THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

APRIL 1961

THE PRODUCTION ENGINEER

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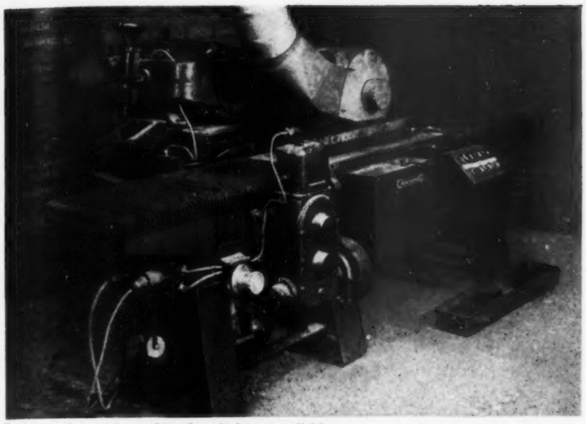
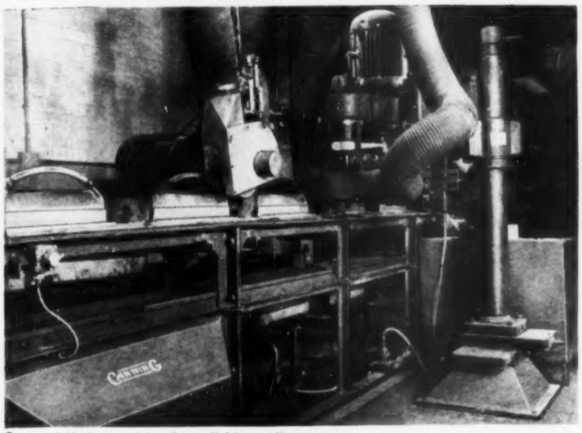
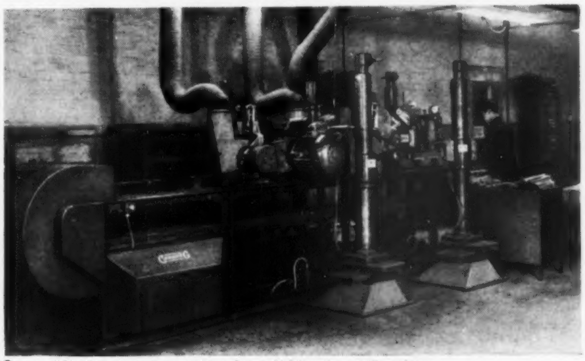


Reciprocating table machine for glazing or polishing.



Over and Under machine for polishing radiator vanes.



Over and Under conveyor machine for polishing door pillar plates.

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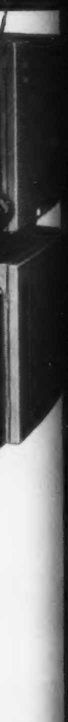

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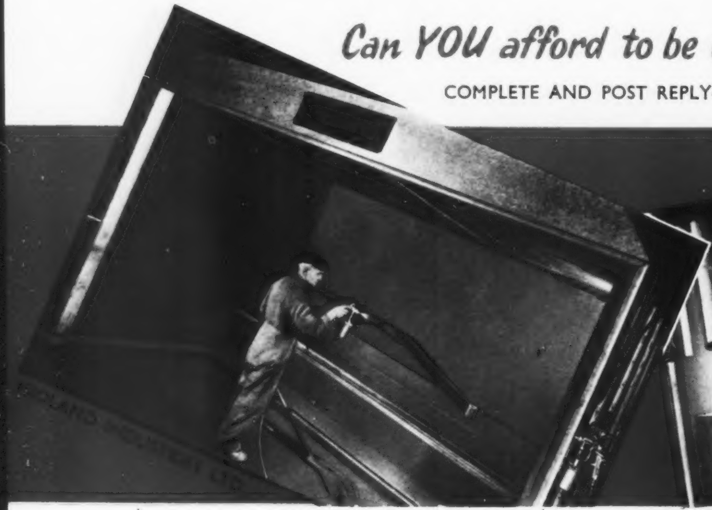

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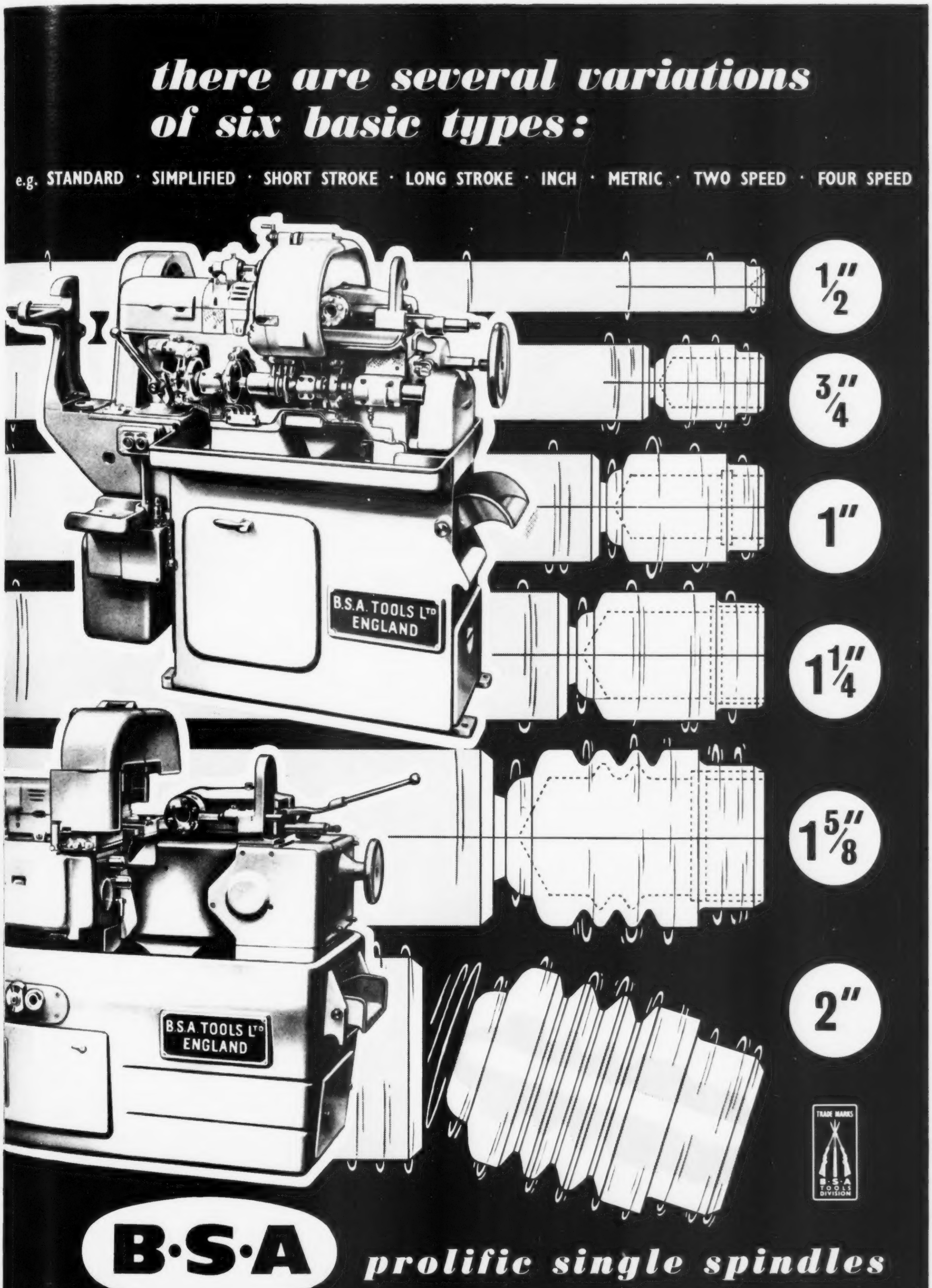
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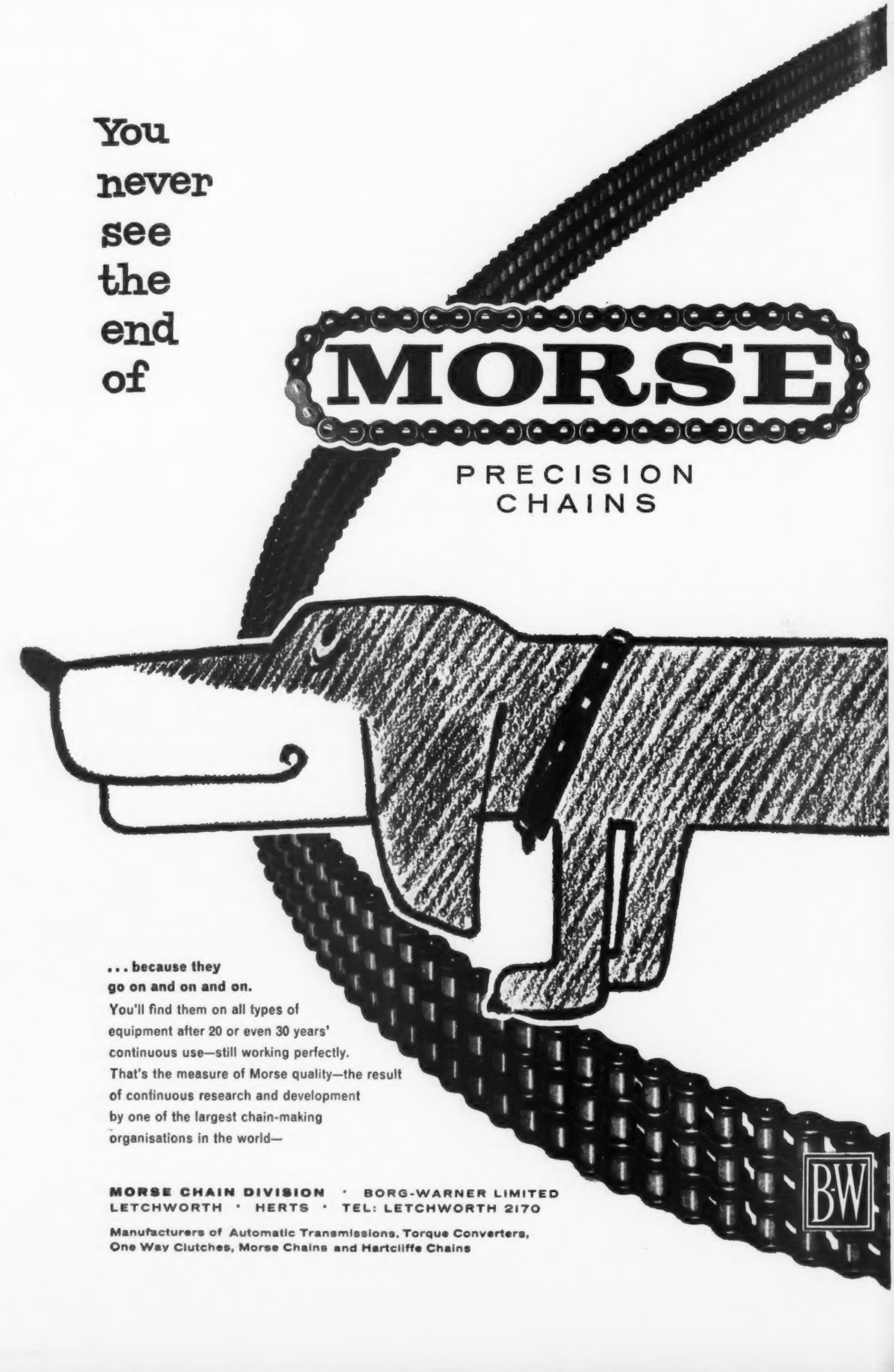
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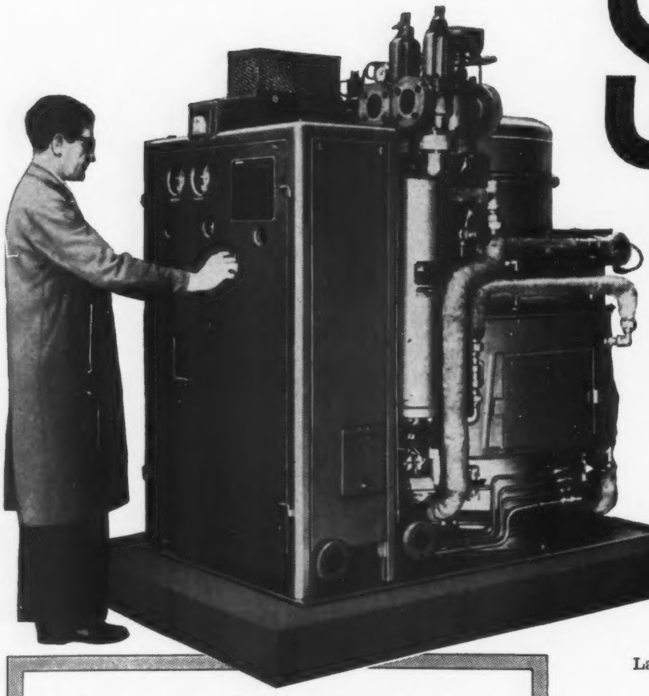

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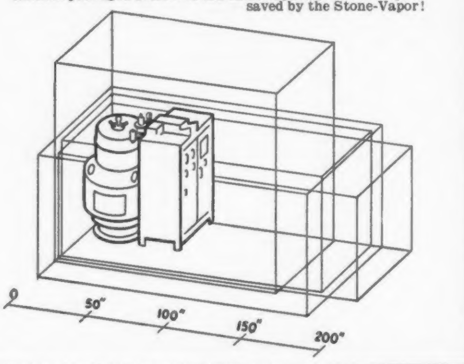

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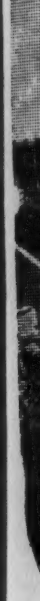

'70' Junior 7" Centre Lathe

2 h.p. motor; 8 speeds, 30-437 r.p.m. also alternatives 44-640 r.p.m., and (when fitted 2-speed motor) 30-874 r.p.m. Sizes are made to admit 45", 54" and 72" between centres.

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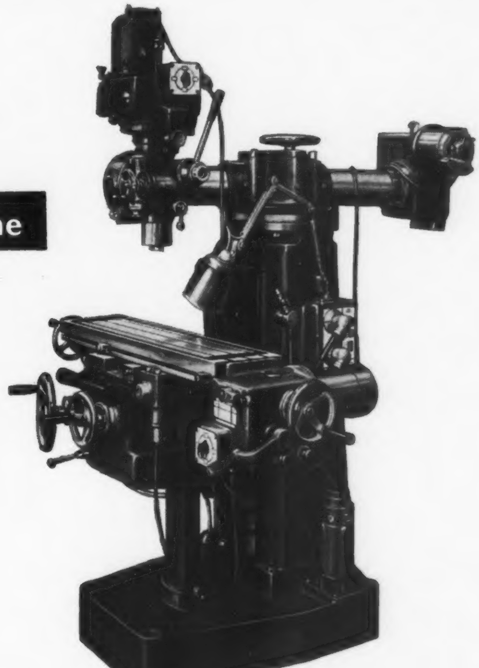

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For milling, boring and jig-boring at any angle, key-way and end milling, die-sinking, mould and pattern-making Table 36" × 9", 10 spindle speeds 100-2,000 r.p.m. (alternative 200-4,000 r.p.m.).

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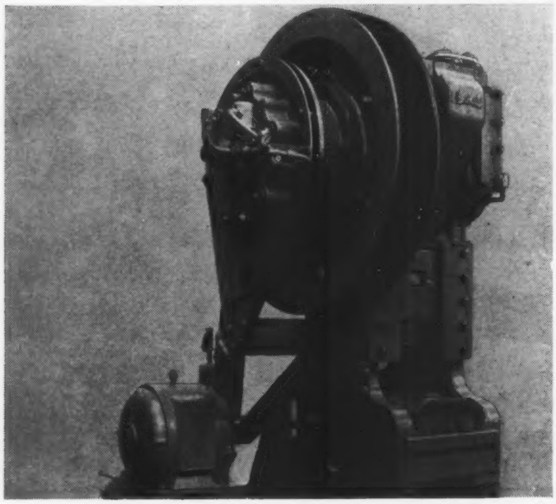
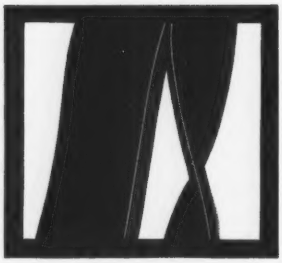
WM33

The flexible nylon-core belt with six big advantages





The Miraclo Nylon-Core Belt has six big advantages which make for greater all-round efficiency. It not only increases output but greatly reduces power consumption, maintenance and overheads.

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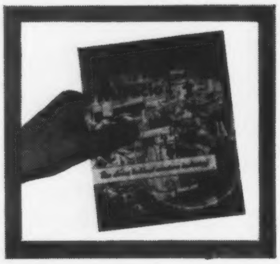
- ★ **Grip**
  with chrome leather driving face
- ★ **Virtually no stretch**
- ★ **Enormous strength**
- ★ **Light weight**
- ★ **Elasticity**



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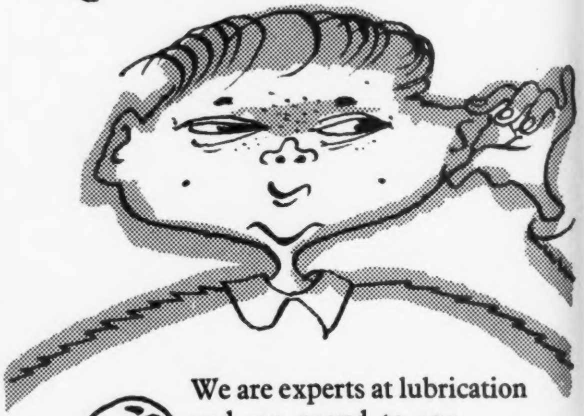

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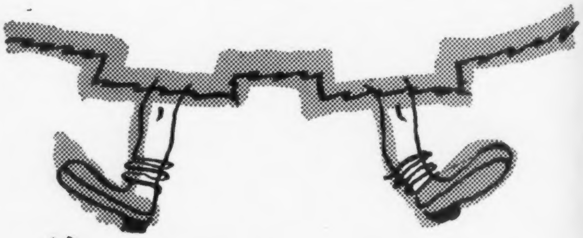

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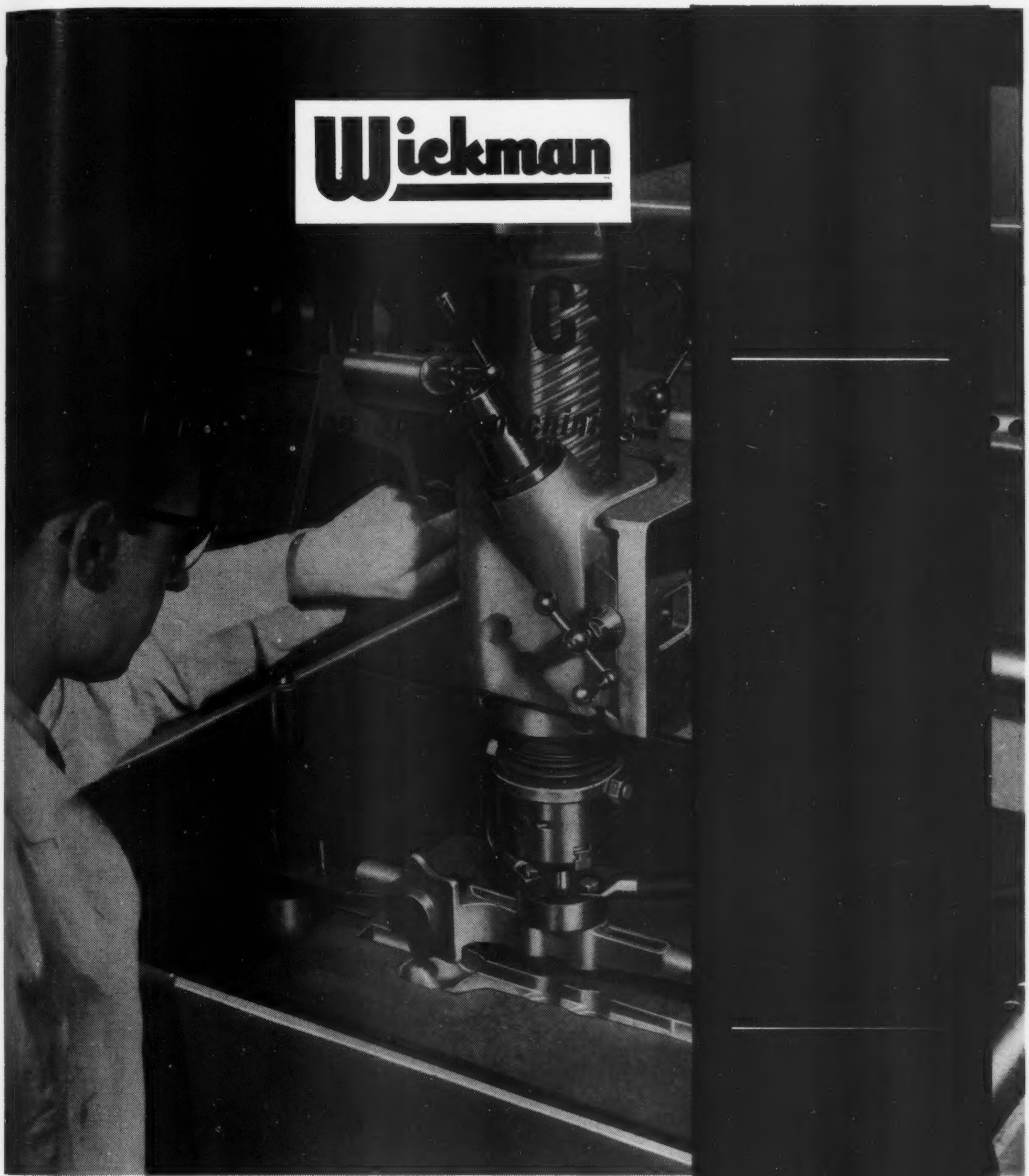

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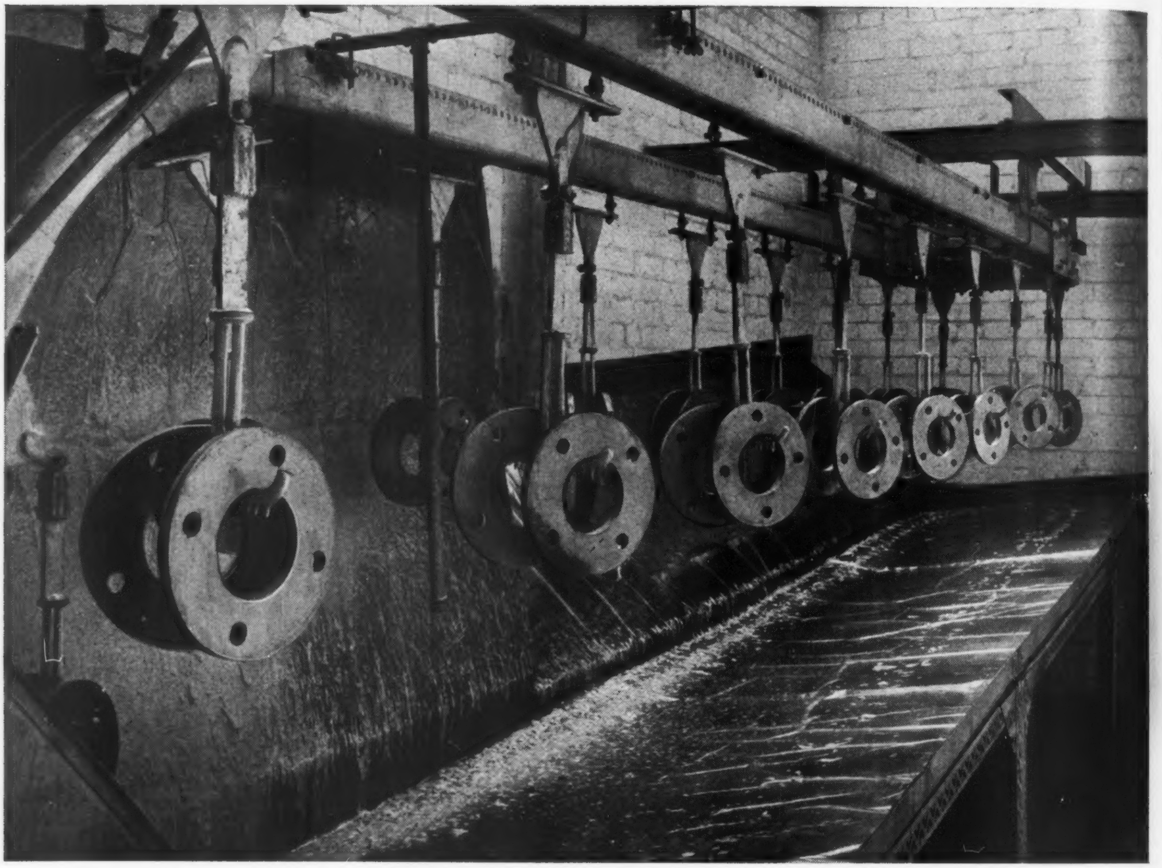
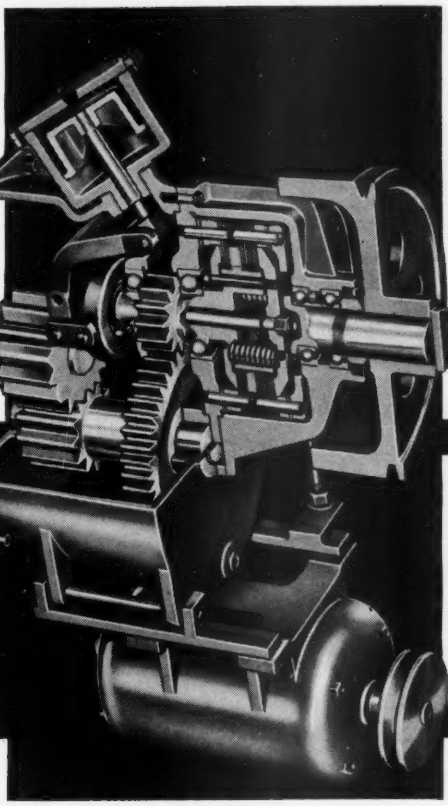


Flanges after receiving protective coating



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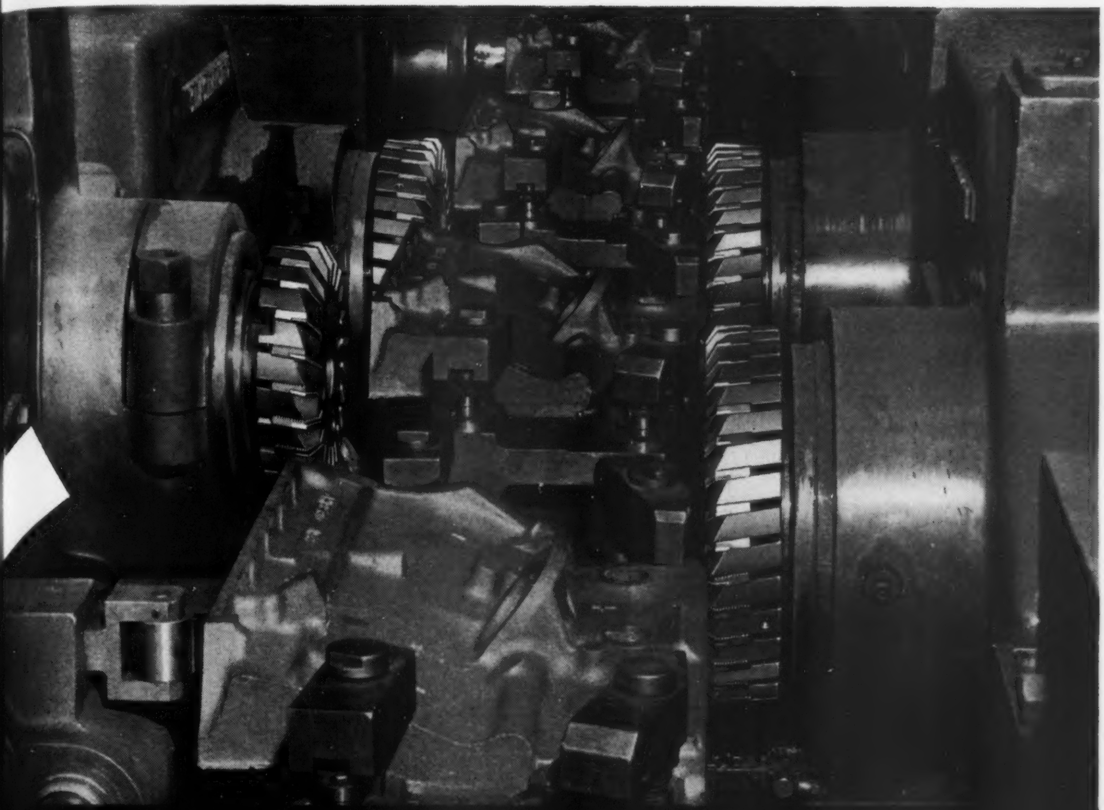

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Set of tool holders comprising:
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1–Sample boring bar.
Independent 4 jaw chuck.
Chuck guard.
Chip tray.
Chip guard at rear of lathe.
Automatic stops for surfacing feeds.
Foundation bolts, levelling screws, plates and wedges.

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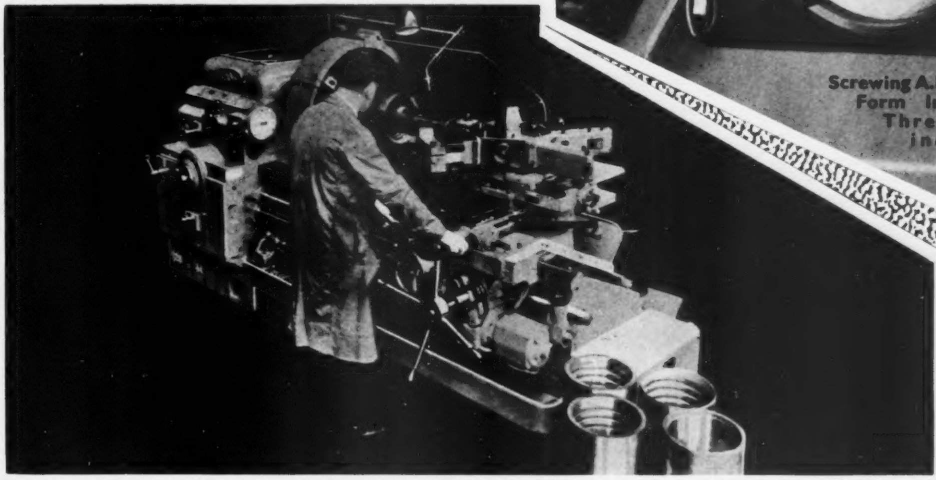
The bed is angled toward the rear for easy chip dispersal and the bed slideways are completely covered by a stainless steel guard.
Three high precision pre-loaded Gamet taper roller bearings support the spindle giving maximum rigidity under cutting loads.
Direct reading dials for cutting speeds, 24 spindle speeds and 60 feeds.
Clutches and brake are hydraulically actuated and do not require adjustment for wear.
Automatic lubrication to fasthead, gear-box, apron and bed-ways.
Hardened strips under the saddle to minimise bed-wear.
Removable centre stop on saddle allows the turret to move beyond the centre of the lathe, making possible the use of maximum size boring bars.
Turret location by long rectangular plunger. Location face at maximum radius ensuring very accurate indexing.
The turret will repeat to ·0008" (0·02 mm) at the end of a 8" (203 mm) long bar.
The turret can be supplied completely tooled up to suit clients requirements.

Screwing A.P.I. Round Form Internal 8 Threads per inch. 9½" taper bore



Swing over bed	32"	813 mm.
Swing over saddle	16"	406 mm.
Admits in front of chuck:		
with minimum bed length	26"	660 mm.
with maximum bed length	44"	1118 mm.
Hole in spindle	4"	102 mm.
Diameter of chuck	24"	610 mm.
24 spindle speeds (forward and reverse)	6·5 to 684 r.p.m.	6·5 to 684 t/m.
60 longitudinal and surfacing normal feeds	·105" to ·0017"	2·67 to ·044 mm.
60 fine feeds at 8 highest spindle speeds	·033" to ·0005"	·84 to ·014 mm.

Diameter of spindle flange. (British Standard)	14½"	362 mm.
Travel of cross slide	17"	432 mm.
Holes in turret	2½"	63 mm.
Size across turret flats	14"	356 mm.
Tool section	1" × 1½"	25 × 38 mm.
Horsepower required	20	15 Kw.
Net weight (minimum bed length)	95 cwt.	4826 Kg.
Nett weight (maximum bed length)	105 cwt.	5334 Kg.

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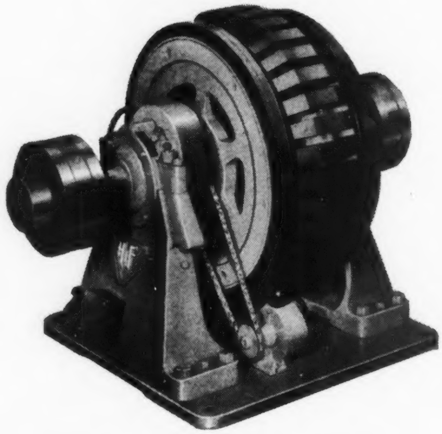

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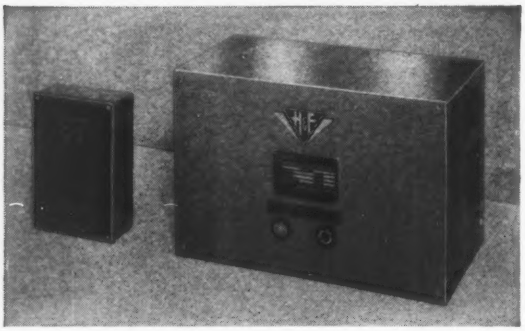

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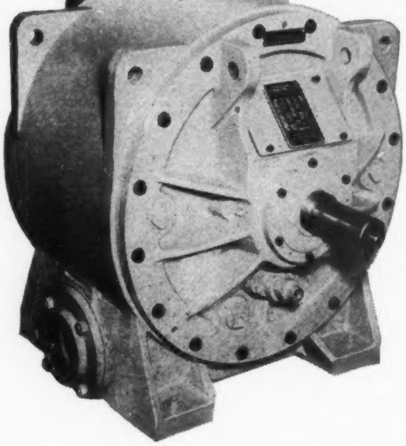

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- Infinitely Variable-Speed
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- Speeds set when stationary or adjusted while running
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- Simple layout
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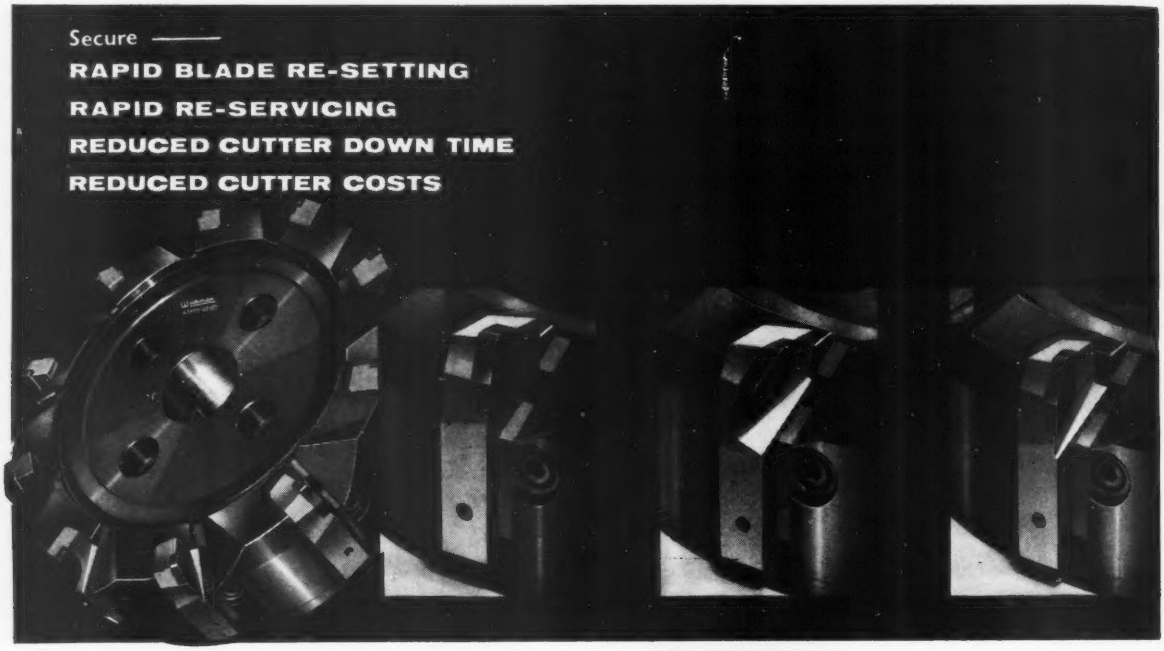
Face Milling Cutters



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GRIND — with special jig

GAUGE — for accuracy

RE-SET — in setting block

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The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 40 NO. 4 APRIL, 1961

A PROGRESS REPORT 1951-1961

by W. F. S. WOODFORD,
Secretary to the Institution.

In January last the Secretary of the Institution completed 10 years in the appointment.

In this progress report, which was presented to the Council at their meeting on 26th January, Mr. Woodford reviews the Institution's activities and development between 1951 and 1961.

I JOINED the Institution's Headquarters Staff in October, 1945. In April, 1950, I was made Acting Secretary and in January, 1951, I was appointed Secretary. Thus, I completed 10 years' service as Secretary, at the Council Meeting held on 26th January, 1961.

Throughout my period as Secretary, I have had the exceptional good fortune to serve under a succession of Presidents and Chairmen of Council of outstanding ability and devotion to the Institution. The high purpose which has inspired the Institution's Principal Officers, and the qualities of leadership which they have displayed, have been example to members and staff alike.

I have been extremely fortunate, also, in my colleagues at Head Office, some of whom have served continuously throughout this period: Mr. Caselton (the Deputy Secretary); Miss Bremner (the Editor of the Journal); Miss Dancer (Editorial Assistant); Mr. Barker and Mr. Hunt (in the Printing Department); Mr. Roberts (in the Accounts Department); and Mrs. Ingram (Head of the Sections Department). Additionally, Miss Allan (Registrar); Miss South (the Librarian); and Mr. Cooper (the Education Officer) have also served throughout most of this period.

The intimate knowledge of Institution affairs which is inherent in this continuity of service, together with the fine spirit of co-operation which exists between the members of the Institution's senior staff, are major factors in contributing to the Institution's progress.

The past 10 years have been extremely active ones for the Institution. The Institution's Associate Membership Examination has operated as a "membership sieve" throughout the whole of this period. When the Examination was introduced in 1951, it was feared that it might have a serious effect on recruitment. Furthermore, during this period, the members' subscriptions have been progressively increased; each increase has again given rise to the fear that it would adversely affect the membership. Nevertheless, in spite of these checks, the membership has grown steadily throughout the period to its present figure of 12,600, which shows an increase of 50% over the 10 years.

no increase in staff

When I was appointed Secretary, I expressed the opinion then, to the Finance and General Purposes Committee, that the number of staff was, in my view, adequate to handle a considerable increase in membership, supposing the level of activities remained the same. It is thanks mainly to the loyalty and strenuous efforts of my colleagues that we have been able to sustain this claim, and the number of staff employed at Head Office today is no more than it was 10 years ago.

Administratively, a permanently watchful eye is kept on Head Office procedures. With the great mass of communications which is handled every month, it is inevitable that errors arise from time to time. Statistically, we have been able to keep our errors to within 2% - 3%. To improve this efficiency would mean a substantial increase in staff which, in my view, would be unjustified.

Several years ago, we called in a firm of Industrial Consultants to look at our Head Office procedures and advise. On the whole, the Consultants were satisfied with our methods but, following their investigation, two important changes were made. We completely changed the method of collecting our membership subscriptions by adopting a revolutionary system. The introduction of this system caused us and our auditors some anxious moments but, after the "bugs" were eliminated, the new system was found to be an immense improvement on the previous old-fashioned methods.

The other change was in our method of dealing with applications for membership. These changes were not so far-reaching as the accounting changes, but they have enabled the Membership Committee and the Registrar considerably to accelerate the process of handling applications for membership.

It is well to recall some of the major events of the decade.

the new headquarters

One of the most important upheavals and a milestone of the Institution's progress, was the acquisition of our new freehold Headquarters — 10 Chesterfield Street. The move from our old building in Portman Square was a nightmare; the building contractors were months behind schedule. We were faced with the choice of moving in to a partly-finished building and suffering the builders, or remaining in our old building at a penalty rent. We chose the former and, although tempers were sorely tried and Headquarters was in a state of near chaos for months, yet we survived!

The response of the membership to the President's appeal for contributions towards the cost of the new Headquarters brought in the handsome sum of nearly £20,000. When we first moved, we had a substantial overdraft at the Bank but I feel that one of the major triumphs of the decade is that, not only is the Institution now completely free of debt, but we have entered an era of budgeting for an annual surplus of 10% of our income.

We have had many notable Conferences during the period. The series of Conferences under the general subject of "Problems of Aircraft Production", which were started by the Southampton Section, went from strength to strength and became established as a major event in the aeronautical calendar. Southampton is no longer a major aircraft centre: if the Aircraft Production Conferences are to continue, the Southampton Section feel that they would be better held in another venue more closely associated with the industry. The Institution owes a substantial debt to those active members in the Southampton Section who promoted these Conferences and developed them to such a high standard.

the Margate Conference

Our National Conferences achieved their peak of success at the Margate Conference in 1955: "The Automatic Factory — What does it Mean?"; the biggest the Institution has ever held, with an attendance of 1,100. We had budgeted for about 750 and it speaks highly for the detailed work of the organising committees that the unexpectedly large attendance did not in any way affect the smooth running of the Conference.

Since then, there has been a steady decline in the attendances at National Conferences, and this seems to be common to all Institutions. The Council of the Institution recognised this a year or so ago, when it decided to abandon the policy of holding annual National Conferences as a matter of routine and habit. It was decided instead to hold National Conferences only as and when subjects of compelling interest present themselves.

The Institution sponsored the establishment of The Production Exhibition at Olympia which was a biennial show. After the third Exhibition, the Council felt that the Institution had done as much as it should in this direction and withdrew.

The annual Summer Schools promoted by the Education Committee have been an important feature in the Institution's programme. The first was held in Oxford in 1950, the next in Durham and then for many years they were held at Ashorne Hill, Warwickshire. A change in the management at Ashorne Hill

somewhat altered the character of the place so, this year, the Summer School was transferred to the College of Aeronautics, Cranfield, and this proved such an admirable venue that it is hoped subsequent Summer Schools may also be held there.

educational progress

Our educational progress during the decade has been steady but not spectacular. Undoubtedly, recognition of the Institution in academic circles is hampered not only by the lack of a Royal Charter but by old-fashioned prejudice. One can, however, report worthwhile gains in the educational field.

At the beginning of the decade, university interest in production engineering was virtually negligible. Today, at least five United Kingdom universities have a substantial measure of production engineering work being done, most of it at post-graduate level. There are signs that the universities are becoming interested in research work in production engineering. In the technical colleges there has been a steady but slow growth in the number of students studying production engineering. In England and Wales, the number of Higher National Certificates in Production Engineering awarded has grown from 240 a year to 600 a year. In Scotland, the Higher National Certificate in Production Engineering was introduced in 1952 and this year saw 73 Certificates awarded. A number of colleges of advanced technology have introduced courses leading to the Dip.Tech. in Production Engineering and there are one or two colleges offering the Higher National Diploma but, as yet, these courses are inadequately supported.

In the Commonwealth, too, our Councils and Sections have made steady progress and have encouraged the establishment of courses in Production Engineering (or Industrial Engineering).

The Education Officer is a most valuable member of Headquarters staff and his services are constantly in demand. He travels widely advising educational establishments, industry and students, on courses for the education and training of production engineers. He has also made visits to India and to Poland on behalf of the Institution.

The end of the decade sees our Associate Membership Examination further revised in its professional content — our Examination is now second to none and the number of examination candidates has risen from about 50 to nearly 500. One of the major tasks that lies ahead is to persuade industry and academic establishments to recognise the significance of the Institution's examination.

the Burke Report

Another major influence on the Institution's affairs was the adoption by the Council of the "Burke Report" in 1951. Two very important changes have stemmed from the report of this Committee. One was the change in the Institution's constitution and structure in the United Kingdom, "The Regional Plan". This made a substantial reduction in the size of the Council, which has had a beneficial effect in the sense that the smaller Council has been more regular in its attendances, which has itself promoted more continuous thought.

The development of the Regions has not been a complete success; indeed, it was not expected to be. In some Regions it is geographically impossible to operate on a close Regional basis and, in such areas, the Regional Plan remains no more that a means of operating the Constitution. In other areas, however, Regionalisation has proved an outstanding success. It has brought about much closer liaison between neighbouring sections and has enabled a number of valuable Regional activities to be established.

The second major change which arose from the Burke Report was a complete change in the Institution's Journal. The old pocket-sized format was abandoned and the larger size adopted. This has been an unqualified success and the Journal, or "The Production Engineer" as it is now known, enjoys a very high reputation. The new Journal enabled the Institution to establish new contractural arrangements with the Advertising Agents and the Journal Printers. In spite of the constant inflationary pressure, the Editorial Committee have managed to ensure that the Journal has continued to pay its way. This is a remarkable achievement when one has in mind that at one stroke, the Postmaster-General increased the postage on the Journal by no less than £5,000 per annum.

introduction of Named Papers

Another notable advance was the introduction of the "Named Papers". During the decade, the presentation of Papers, on an annual or bi-annual basis, has been established to commemorate the work and the association with the Institution of distinguished production engineers, viz.:

The Sir Alfred Herbert Paper.
The George Bray Memorial Lecture.
The Lord Sempill Paper.
The Viscount Nuffield Paper.
The E. W. Hancock Paper.

Two additional awards have been introduced in the period: the J. D. Scaife Medal, which is for the best Paper printed in the Journal in any year, other than those Papers presented to Sections or Regions, or Named Papers; and the Sir Walter Puckey Prize for the outstanding project on a Production Engineering subject in a Diploma of Technology (Eng.) Course, which has been awarded this year for the first time.

The appointment of a full-time Technical Officer in September, 1957, gave a much-needed impetus to the work of the Institution's Research and Technical Committees. The Research Committee and its Sub-Committees, and the Standards Committee and its Sub-Committees, had long felt the need for full-time technical help.

A Graduate Member of the Institution, Mr. Ian King, was appointed to work under the general jurisdiction of Mr. Cooper, Mr. King did most valuable work in establishing the appointment. He introduced Technical Seminars as part of our programme, which

have proved most successful, and also played an important part in establishing the Materials Handling Group. Mr. King has now returned to industrial life but he has the satisfaction of knowing that, during the three years he was with us, he made a very important contribution to our progress. It is hoped to replace Mr. King with another Technical Officer in the near future.

The Institution's Library, which had been destroyed by fire during the War, was reconstituted and named "The Hazleton Memorial Library". The Library operates very much on the lines of an industrial intelligence service: a service which is much appreciated by members and, from time to time, extended also to non-members. A Library catalogue was first published in 1955 and subsequent revisions have been published from time to time.

The most important happening to me personally during the period was undoubtedly the extensive tour abroad which I made for the Institution from January to April, 1960. The Report of this tour has only recently been published in the Journal so I will make no reference to it, other than to say that the personal contacts which have been established with Headquarters of the Institution and its Councils and Sections in far distant parts of the world will, I hope, prove a great source of strength to the Institution in the future.

The greatest disappointment of the period was the failure of our Petition for a Royal Charter of Incorporation.

At this present moment we are poised, as it were, gathering strength for further advances. The Finance and General Purposes Committee, under the Chairmanship of Mr. Turner, is busy considering proposals to improve the Institution's policy and administration, which have been set out in a memorandum by the President.

growing demand for production engineers

I am absolutely convinced that the future for production engineering is infinitely large. I believe that, in the not-too-distant future, production engineering (under whatever name it may be known) will be the dominating technology throughout the world. The rapid increase of world population, coupled with a greatly accelerated industrial expansion, will demand more and more production engineers, who will have to be trained to ever higher standards of skill and professional competence. This is especially true in the field of production management and the Institution will be well-advised to pay great attention to its programme of activities to subjects touching upon human relations.

If I were called upon to foretell anything for the next 10 years, I feel confident that, if the Institution continues in its present vigorous course, then:

1. we may achieve the honour of a Royal Charter;
2. we may see the establishment of at least six chairs in Production Engineering at leading Universities in the United Kingdom;
3. we shall greatly extend our influence throughout the Commonwealth (and perhaps other parts of the world);
4. we shall double the membership.

COUNCIL ELECTIONS, 1961-1962

A notice calling for nominations to fill nine vacancies on Council, for the year commencing, 1st July, 1961, will be published in May.

The vacancies will be for eight Members and one Associate Member. All Members and Associate Members of the Institution are eligible for election. Before nominating candidates for election their consent must be obtained.

Candidates for election must be nominated in writing by three Corporate Members of the Institution (Corporate Members: Honorary Members, Members and Associate Members). In addition, each Section Committee may nominate one candidate.

THE WORLD'S FUTURE TRANSPORT REQUIREMENTS

by Sir PERCY HUNTING, F.C.I.S., M.Inst.Pet.

Lately Chairman,

The Hunting Group of Companies

Sir Percy Hunting, who retired from the Chairmanship of The Hunting Group of Shipping, Oil, Aviation, Survey and Engineering Companies at the end of 1960, represents the third generation in the Hunting family business, which was founded by his grandfather, with the purchase of a sailing ship, in 1874.

Sir Percy has been the guiding hand behind the Group's remarkable expansion over the past 35 years. Educated at Loretto, he served his time as a marine engineer with The North Eastern Marine Company, Wallsend-on-Tyne. He subsequently served in the Northumberland Fusiliers and was seconded to the Royal Flying Corps in the First World War. He is succeeded in the Chairmanship by his brother, Mr. G. L. Hunting.

This Paper was presented to the Institution as The 1961 Lord Sempill Paper, on 25th January last, at The Royal Aeronautical Society, London.

I AM somewhat puzzled as to why you should have invited a shipowner — albeit one with an engineering background — to read a Paper on aviation, but I take heart from the fact that, over the past fifteen years or so, I have been intimately and aggressively concerned with air transport as an independent operator.

I have seen and studied a number of earlier Papers in the Lord Sempill series, and it is with some misgiving that I follow such illustrious and well-qualified speakers. Lord Sempill, after whom this series of Papers is named, has been active in the aircraft world for 50 years. He was a pioneer of the light aircraft industry with which my Group has been so closely concerned.

He is not only a Member but was twice President of your Institution, and is also a Past Chairman and Past President of the Royal Aeronautical Society.

acknowledgments

I wish to record my thanks to Air Commodore Nowell of my Headquarters Staff for his valuable assistance to me in the preparation of this Paper, and to Mr. R. G. Worcester of Aviation Studies (International) Ltd. for his constructive advice in drafting and his assistance in the selection of the various graphs and statistics which have been included.

scope of Paper

The theme originally suggested to me was "The World's Future Transport Requirements", designed to cover both "The Transport Industry's Requirements" and "The Manufacturing Industry's Proposals". Although I have had some direct association

with the aircraft industry, this has been confined to the manufacture of light training aircraft. My own particular air hobby-horse has always been air transport and so I suggested that for this Paper I should concentrate on "The Transport Industry's Requirements", leaving the manufacturing proposals to someone more fully qualified to discuss them.

My part of the subject covers a very wide field, including all classes of transport aircraft considered at a time of radical change leading to aircraft with supersonic performance. I regret that time will not permit me to enlarge, as I should wish, on the associated problems of passenger and freight handling at airports and the layout of airport terminals generally.

Having been brought up in shipping and having to some extent basked in the reflected sunshine of Britain's foremost place in the world of shipping, I have always approached the problems and the possibilities of air transport in much the same way as those of shipping. My great concern has always been to see that the United Kingdom and Commonwealth achieve and maintain in the air the same important position held for several hundreds of years at sea. The potential is certainly there, but over the years I have been discouraged at the lack of policy and inspired leadership necessary to turn potential into economic fact. I put this down to the effects of our environment of shipping. We are an island nation and, for hundreds of years, have depended on ships and on those who owned and operated them. When, after the Second World War, British shipowners were openly prepared to enter the field of aviation, the State came along and said: "We don't want you; *we* will manage this ourselves." In adopting this attitude, the State was — and is — forging a weapon which will gradually kill British shipping. In the long run, I see no alternative to an almost total preponderance of aviation over all other forms of transport.

In this Paper I shall be attempting to cover some forty years — past, present and future — of British air transport, beginning with the 1950s and looking ahead towards the end of this century. This, I know, is a tall order but I hope that what I have to say will at least be thought-provoking. I hope, too, that having very recently stepped down from the Chairmanship of my family business, I shall have a little more time to devote to this fascinating subject.

1950/1960 — the past generation

The decade of the 1950s saw the beginnings of the change-over from piston engines to turboprops and turbojets as power plants for transport aircraft. By the end of 1959 the Vickers Viscount had become completely established throughout the world and 130 jet transports had been delivered out of the 401 ordered by that time. Even so, these 130 turbojet transports represented only some 2.5% of the total free world fleet of 4,950 aircraft of over 20,000 lb. all-up weight. Piston-engined aircraft still accounted for 84.4% (49.5% twins and 34.9% four-engined) and turboprops for 12.9% of the total.

The Comet 1 went into service at the beginning of the fifties and the prototype Boeing 707 flew in mid-1954, but throughout this decade the airline industry as a whole seemed uncertain of the economic impact of the jetliners and how the new equipment would be financed. As late as June 1958, I.C.A.O. expressed grave doubts about the economic viability of long-range jet aircraft operations.

Thus, although almost every airline — large and small — decided that they must get into the jet airliner business, the latter half of the fifties saw a flurry of efforts to explore the possibilities of collective action in the operational, technical, and even political fields. The most ambitious of these was Air Union, formed in the wake of the European Economic Community. This consortium has still to be worked out in detail, but it has as its main object a more equitable balancing of utilisation and facilities with provision for joint selling. The period saw another, looser, arrangement between Swissair and S.A.S. with agreement limited to aircraft procurement and maintenance co-ordination. (At the time of writing, K.L.M. are considering joining this consortium.)

Britain's State airlines pioneered the controversial revenue-pooling system and in the bilateral consortium between B.E.A. and Olympic, this principle was extended to equipment and other fields of co-ordination. The BOAC/Air India/Qantas co-operative arrangement is a variation on the same theme, pooling services over combined networks and with each airline acting as sales agent for the others.

Among further consortium proposals in the discussion stage are:

(a) that between Chile, Ecuador, Colombia, and Peru;

(b) the Pan-Arab airline — United Arab Airways — composed of members of the Arab League.

These are in a sense defensive measures prompted by the fear that, with the steep increase in capacity offered by the new jetliners, unless traffic can be found to maintain load factors nearer 60% than 55%, nothing in airline history will be more economically and financially punishing than the jetliner. Individual airlines had also to consider the need for increasing capital expenditure for replacing their obsolete shorter-range equipment with aircraft of greatly increased cost. For instance, the BAC 107 airliner can hardly be offered at less than twice the price of the Fokker F27, and the new medium jets will be over twice the price of the Viscount 800.

All of these rising costs are being seen as inevitable, and collective agreements between carriers to face the uncertain future together are understandable measures for protection. We can expect more of them, and hope that they may be one of the means of bringing flying within the financial reach of a much wider cross-section of the public.

What were the trends of air traffic in the fifties? (See Tables 1, 2 and 3.)

WORLD REVENUE TRAFFIC 1945-1960 (SCHEDULED SERVICES)

TABLE I

YEAR	Kilometres Flown	Hours Flown	Passengers Carried	Passenger-Kilometres	Cargo Tonne-Kilometres	Mail Tonne-Kilometres	Average number of: Passengers per aircraft	Kilometres flown per passenger	Kilometres flown per hour
			Millions						
1960	3 180	8·9	108	111 000	2 180	600	35	1 030	355
1959	3 070	8·9	98	97 000	1 920	520	32	995	345
1958	2 920	8·7	87	85 000	1 670	470	29	975	335
1957	2 830	8·7	86	81 000	1 630	430	29	950	325
1956	2 540	8·0	77	71 000	1 480	400	28	925	320
1955	2 290	7·3	68	61 000	1 300	370	27	905	315
1954	2 050	6·7	59	52 000	1 100	330	25	895	310
1953	1 920	6·4	52	46 000	1 040	280	24	885	300
1952	1 760	6·0	46	40 000	990	250	23	875	295
1951	1 610	5·6	42	35 000	910	230	22	830	290
1950	1 440	5·0	31	28 000	770	200	19	875	285
1949	1 350	4·8	27	24 000	570	190	18	880	280
1948	1 270	4·6	24	21 000	420	170	17	890	275
1947	1 140	4·2	21	19 000	270	130	17	900	270
1946	940	3·8	18	16 000	120	100	17	850	250
1945	600	2·5	9	8 000	110	130	13	880	240

YEARS	ANNUAL INCREASE OR DECREASE								
1959-60	+ 4%	0%	+ 10%	+ 14%	+ 14%	+ 15%	+ 9%	+ 4%	+ 3%
1958-59	+ 5%	+ 2%	+ 13%	+ 14%	+ 15%	+ 11%	+ 10%	+ 2%	+ 3%
1957-58	+ 3%	0%	+ 1%	+ 5%	+ 2%	+ 9%	0%	+ 3%	+ 3%
1956-57	+ 11%	+ 9%	+ 12%	+ 14%	+ 10%	+ 8%	+ 4%	+ 3%	+ 2%
1955-56	+ 11%	+ 10%	+ 13%	+ 16%	+ 14%	+ 8%	+ 4%	+ 2%	+ 2%
1954-55	+ 12%	+ 9%	+ 15%	+ 17%	+ 18%	+ 12%	+ 8%	+ 1%	+ 2%
1953-54	+ 7%	+ 5%	+ 13%	+ 13%	+ 6%	+ 18%	+ 4%	+ 1%	+ 3%
1952-53	+ 9%	+ 7%	+ 13%	+ 15%	+ 5%	+ 12%	+ 4%	+ 1%	+ 2%
1951-52	+ 9%	+ 7%	+ 10%	+ 14%	+ 9%	+ 9%	+ 5%	+ 5%	+ 2%
1950-51	+ 12%	+ 12%	+ 35%	+ 25%	+ 18%	+ 15%	+ 16%	— 5%	+ 2%
1949-50	+ 7%	+ 4%	+ 15%	+ 17%	+ 35%	+ 5%	+ 6%	— 1%	+ 2%
1948-49	+ 6%	+ 4%	+ 13%	+ 14%	+ 36%	+ 12%	+ 6%	— 1%	+ 2%
1947-48	+ 11%	+ 10%	+ 14%	+ 11%	+ 56%	+ 31%	0%	— 1%	+ 2%
1946-47	+ 21%	+ 11%	+ 17%	+ 19%	+ 125%	+ 30%	0%	+ 6%	+ 8%
1945-46	+ 57%	+ 52%	+ 100%	+ 100%	+ 9%	— 23%	+ 31%	— 3%	+ 4%

Exclusions: The People's Republic of China, the USSR, and other States which were not members of ICAO at 31 December 1960.

ICAO STATISTICS SECTION (December 1960)

TRANSATLANTIC PASSENGER TRAFFIC IN THE FIRST SIX MONTHS OF 1960

Sea Traffic, North America—Europe

TABLE 2

Month	1st Class: Transport Capacity	1st Class: Passengers carried	1st Class: % occupied	Cabin Class: Transport Capacity	Cabin Class: Passengers carried	Cabin Class: % occupied	Tourist Class: Transport Capacity	Tourist Class: Passengers carried	Tourist Class: % occupied	Total: Transport Capacity	Total: Passengers carried	Total: % occupied	% occupied in 1959	% variation of passengers carried as compared with the corresponding period of 1959
January	5,350	2,795	52	3,995	1,284	32	12,917	5,673	44	22,262	9,752	44	43	— 15
February	7,500	4,300	57	5,794	2,097	36	16,369	7,269	44	29,663	13,666	46	43	+ 22
March	9,983	6,166	62	5,715	3,684	64	27,051	16,234	60	42,749	26,084	61	52	+ 15
April	12,007	8,673	72	6,982	5,695	82	30,842	23,659	77	49,831	38,027	76	66	+ 4
May	15,140	10,281	68	9,393	8,446	90	39,130	30,808	79	63,663	49,535	78	74	0
June	18,728	17,533	94	10,870	10,471	96	49,289	47,151	96	78,887	75,155	95	93	+ 13
TOTAL	68,708	49,748	72	42,749	31,677	74	175,598	130,794	74	287,055	212,219	74	68	+ 7

Source: Atlantic Conference.

TRANSATLANTIC PASSENGER TRAFFIC IN THE FIRST SIX MONTHS OF 1960

Air Traffic, North America—Europe

TABLE 3

Month	1st Class			Cabin Class			Tourist Class			Total			% occupied in 1959	% variation of passengers carried as compared with the corresponding period of 1959
	Transport Capacity	Passengers carried	% occupied	Transport Capacity	Passengers carried	% occupied	Transport Capacity	Passengers carried	% occupied	Transport Capacity	Passengers carried	% occupied		
January	19,061	9,297	49	2,813	772	27	43,759	23,652	54	65,633	33,721	51	48	+ 21
February	18,699	8,916	48	2,679	751	28	42,196	21,668	51	63,574	31,335	49	50	+ 21
March	19,435	11,045	57	2,384	827	35	48,503	30,499	63	70,322	42,371	60	64	+ 11
April	20,363	14,454	71	2,021	1,156	57	60,850	48,236	79	83,234	63,846	77	66	+ 38
May	22,792	15,428	68	1,419	766	54	82,230	68,055	83	106,441	84,249	79	72	+ 26
June	27,411	19,865	73	778	597	77	122,477	115,728	95	150,666	136,190	90	91	+ 27
TOTAL	127,761	79,005	62	12,094	4,869	40	400,015	307,838	77	539,870	391,712	73	69	+ 26

Source: International Air Transport Association (I.A.T.A.)

The average increase in passengers carried during the period 1954-59 was 13.8% on international routes and 10% on domestic routes. Increases in air cargo during this period were 15.5% international and 9.1% domestic. Taken all round, however, there is unmistakable evidence of an overall decline in the rate of growth of traffic, which averaged 14% for the years 1950-57, but fell to 9.7% during the last three years of this period. The United States is responsible for over 60% of the free world's totals, and so in the U.S. recession year of 1958 the drastic reduction in American domestic flying pulled down the world figure.

All this is the background to the wide tendency towards rate increases as proposed by governments and by the airlines themselves as a solution to their troubles. But increasing rates is, at best, a questionable policy, for it tends to alienate just that section of the market which the airlines want, above all, to cultivate — the lower-income groups. It is a salutary thought that, as revealed in a 1955 U.S. travel review, 75% of Americans have never flown commercially, yet Americans love to travel. The same survey indicated that only 30% of American adults had never taken a rail journey. The average American has about 2½ times the spending money of even the average European, and so it follows that the number of " different " Europeans who travel must be extremely small. In general, 30% of passenger traffic is composed of 3% of the population who fly more than ten times each year. Much of the intra-European traffic is American and the Paris airport traffic returns have shown that in a breakdown of traffic between Paris and other European cities, nationals of the two cities concerned are naturally the most frequent travellers but that Americans often come a good second — ahead of the nationals of other neighbouring countries. (See Figures 1 and 2.)

It seems difficult to justify a fare rise in terms of national economic policy, yet there is the paradox of it being at the same time difficult to justify *not* raising the fares in terms of airline viability. It is, therefore, a case of balancing the long-term interests of the travelling public with the immediate relief needed by the airlines to obtain a quick rise in revenue to match the steep rise in expenses of wide-scale introduction of jetliners to routes.

In his January 1958 " State of the Union " speech, President Eisenhower said : " There are critical questions here for the leadership of business and labour as well as for Government. Business concerns must re-examine their policies and practices. Price increases that are unwarranted by costs or that attempt to recapture investment outlays too quickly not only lower the purchasing power of the dollar but may be self-defeating by causing a restriction of markets; lower output; under-utilisation of capacity; and a narrowing of the return on capital investment." This is surely applicable to the whole airline industry.

At about the same time in 1958 the President of National Airlines said : " The airlines need more traffic in order to produce more revenue. An increase in fares at a time when industry load factors are declining is contrary to good business judgment." (See Graph 1.)

There seem to be three ways to obtain a fare decrease :

(i) Lower the direct operating costs (D.O.C.) of the aircraft employed.

(ii) Lower the indirect operating costs (I.D.O.C.).

(iii) Shorten the leg-room for airline passengers.

The only real way to obtain a satisfactory reduction of direct operating costs is by invoking new technology and in particular by directing advances in the state of the art towards improving economy. Recently, American Airlines said bluntly that it wants a new and leaner concept of engine. This must be regarded as of equal importance to the improvement of the aircraft themselves. Perhaps one of the most important factors in the economics of air transport, especially as aircraft become faster and faster, is the turn-around time at airports. I shall have more to say about this later in the Paper.

When the jetliners were first coming into service both manufacturers and operators made confident claims that they would improve on the economics of the last generation of piston-engined aircraft.

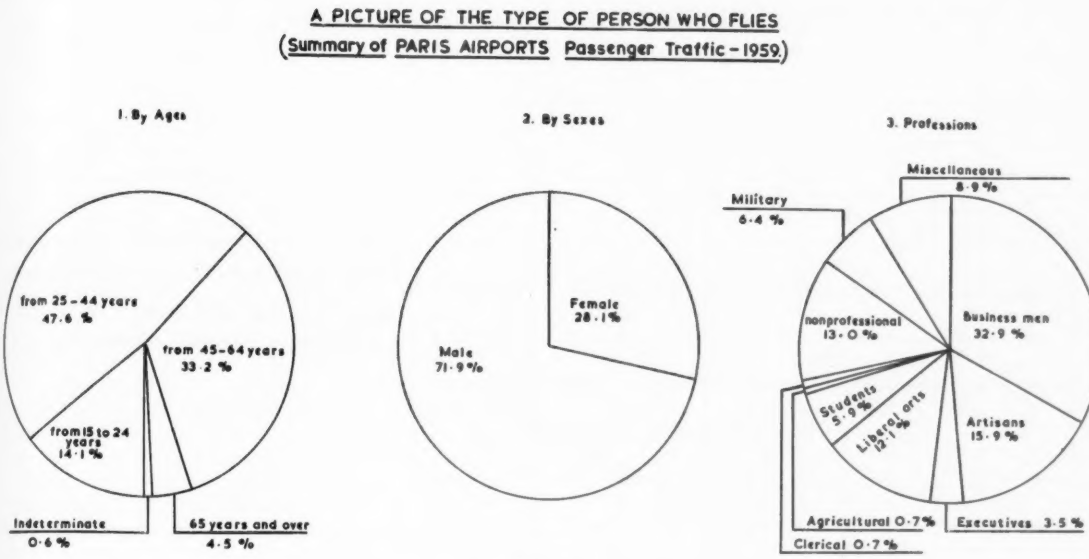

A PICTURE OF THE TYPE OF PERSON WHO FLIES
(Summary of PARIS AIRPORTS Passenger Traffic - 1959.)
1. By Ages
from 25 - 44 years 47.6 %
from 45-64 years 33.2 %
from 15 to 24 years 14.1 %
Indeterminate 0.6 %
65 years and over 4.5 %
2. By Sexes
Female 28.1 %
Male 71.9 %
3. Professions
Miscellaneous 8.9 %
Military 6.4 %
nonprofessional 13.0 %
Business men 32.9 %
Students 5.9 %
Liberal arts 12.1 %
Artisans 15.9 %
Agricultural 0.7 %
Executives 3.5 %
Clerical 0.7 %

Fig. 1.

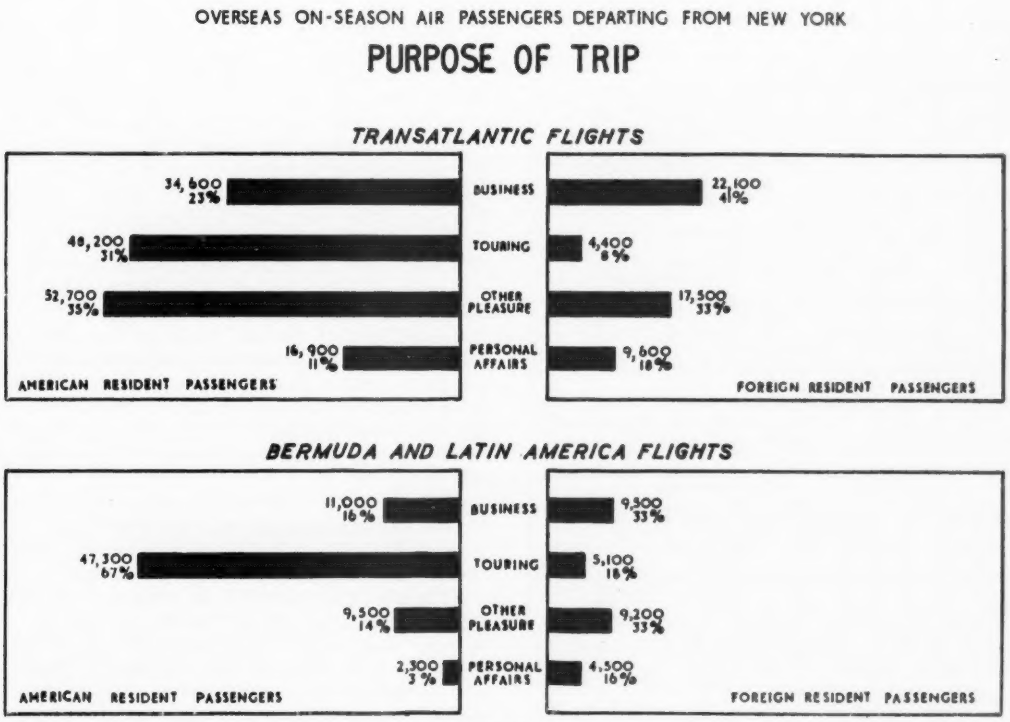
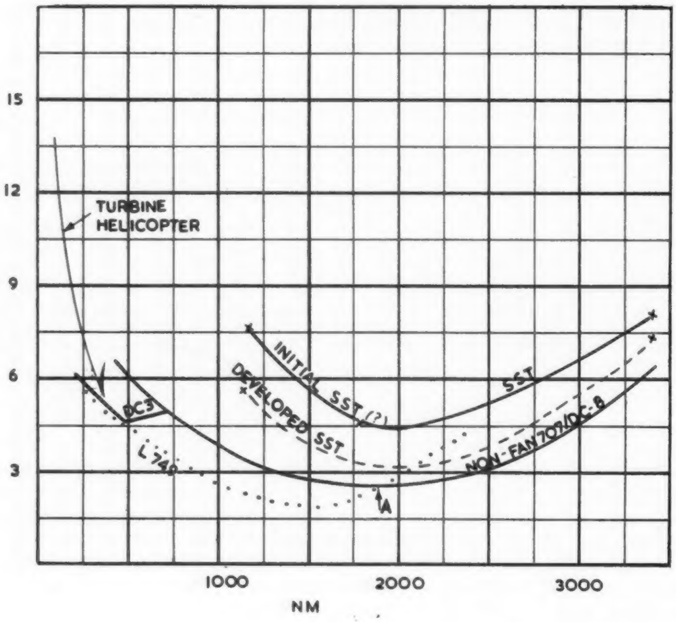
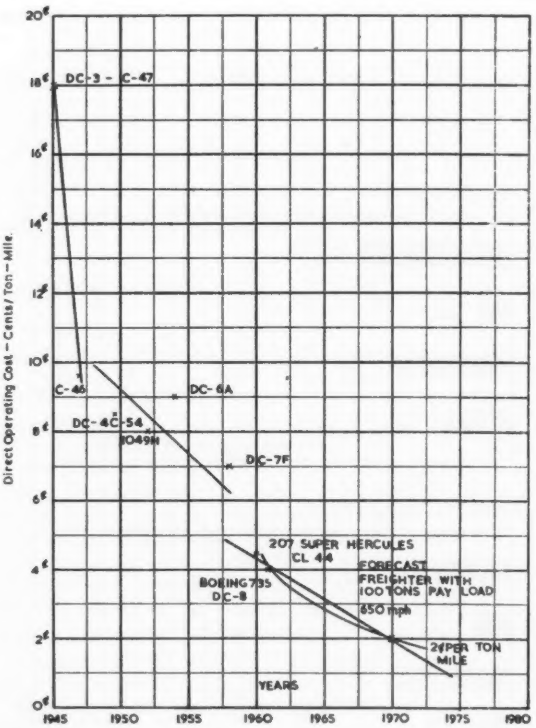

OVERSEAS ON-SEASON AIR PASSENGERS DEPARTING FROM NEW YORK
PURPOSE OF TRIP
TRANSATLANTIC FLIGHTS
34,600 23%
BUSINESS
22,100 41%
48,200 31%
TOURING
4,400 8%
52,700 35%
OTHER PLEASURE
17,500 33%
16,900 11%
PERSONAL AFFAIRS
9,600 18%
AMERICAN RESIDENT PASSENGERS
FOREIGN RESIDENT PASSENGERS
BERMUDA AND LATIN AMERICA FLIGHTS
11,000 16%
BUSINESS
9,500 33%
47,300 67%
TOURING
5,100 18%
9,500 14%
OTHER PLEASURE
9,200 33%
2,300 3%
PERSONAL AFFAIRS
4,500 16%
AMERICAN RESIDENT PASSENGERS
FOREIGN RESIDENT PASSENGERS

Fig. 2.



Graph 1. Cost comparison by aircraft type (direct operating costs—cents per seat mile).

Note : Point " A " (2.74 cents) from I.C.A.O. Document 8087/925, August, 1960.



Graph 2. Freight aircraft — operating costs (record to 1960 and forecast to 1980).

(See Graph 2.) Some went so far as to predict that the Boeing 707-320 and the Douglas DC-8 would show a decrease in D.O.C. of up to 30% by comparison with the Lockheed L1049G and Douglas DC-6. However, these forecasts were soon falsified by events. I.C.A.O. suspected this when in its report " The Economics of Long Range Jet Aircraft " it said : " The unit operating costs of the new turbine-powered aircraft are inevitably unknown except in theory." Later in 1959 I.C.A.O. reported : " Slightly less encouraging is the experience gained with direct operating costs. Three United States carriers — American, Pan Am and TWA — operating Boeing 707s in the first three quarters of 1959 had unit operating costs in terms of cents per available seat mile varying from 1.65 to 2.74, but averaging very close to 2 cents. It had been claimed that the operating costs of the jets would be somewhat lower than those of turboprops and piston-engined aircraft, but the figures thus far realised have turned out to be very similar to those shown in the operation of the Lockheed Electra, Viscount 745, the DC-6 and DC-7 — all of which approximate 2 cents per seat mile."

While, as I.C.A.O. points out, the results as assessed in 1960 are still inconclusive, it is clear that no large drop in D.O.C.s is likely while passenger leg-room remains at the presently agreed dimensions.

Little has so far been said or written about indirect operating costs which, at something like 100% of D.O.C.s, have always been accepted as one of the laws of nature. However, I am one of those who feel — very strongly — that these indirect costs are susceptible to considerable reduction. There are altogether too many expensive frills associated with

the support of actual airline operations. Most of them could be clipped and many of them could be cut out completely.

Let me give a few examples.

A determined drive to increase the productivity of both technical and administrative staffs would stop the present tendency for additional staff to creep up on management. There could well be a more frugal look generally towards floor space, facilities and buildings which could do so much to reduce I.D.O.C.s. The turbine-engined airliners — with and without propellers — have already reached a high standard of reliability and durability, and whilst there seems to be an approaching limit to hours between overhauls, the full benefits of turbine reliability have yet to work themselves through the airline systems. This could and should lead to the disbandment of some complete maintenance shops — I have never been able to understand the wasteful duplication of engineering effort by the two Corporations at London Airport. Most of this work could more effectively and certainly more economically be put out to contract and the balance could well be integrated as one service for both Corporations. We do not see the major shipping lines carrying out their own ships' overhauls — they certainly would if this were more economical.

An interesting and practical arrangement has been made by the Boeing Airplane Company with the various airlines operating its 707 and 720 jet aircraft. Under this arrangement, which recalls the Lockheed Pool Arrangement, a number of spares-holding depots have been established in various parts of the world and the airline customers can draw spare parts as required. This is obviously a great advantage, representing the saving of 50%, for instance, in engine spares holdings.

The same arguments apply to the training of flying, technical and administrative personnel. A very great saving in overheads could be achieved by the maximum possible standardisation and integration of training schemes. The tendency for individual airlines to be 100% self-contained and self-sufficient is grossly extravagant.

The third way of cutting costs by reducing leg-room could well be accomplished, for leg-room is a function of elapsed time. In many London theatres the "pitch" between rows of seats is only 24 inches (in at least one theatre it is only 20 inches) and patrons do not seem to complain about sitting there for 2½ to 3 hours. Airline passengers do, however, complain about having to travel at T34 pitch for long periods of up to 16 hours. The rigid limit of T34 irrespective of sector distance is a mistake — it could certainly be considerably less for short distances. People who are prepared to put up with severe discomfort for two hours or more in a theatre in order to save a few shillings, would certainly be willing to save several pounds by accepting less comfortable air travel conditions if the choice were open to them. For short flight stages of up to 2 hours airlines could, in fact, plan on a passenger density over 90% of that of current air freight — 9 lb./cu. ft. With as many passengers as this — say 200 in a cabin 65 ft. long — the limiting factor on present aircraft would be cabin ventilation! I should like to be thoroughly provocative and suggest for serious consideration by the airlines and their insurers, the possibility of carrying a proportion of standing passengers on the shorter journeys of the future. For high-speed journeys between London and Paris, Brussels, Amsterdam, etc., standing passengers could be carried at very low fares.

In 1959 some of the British Independent Airlines undertook to operate services between this country and various parts of the Commonwealth at fares very little more than half of the tourist class fares then in force. They did not receive official permission to do this, but the support received from potential travellers at all points along the suggested routes was proof that lower fares would mean greatly increased load factors. Silver City's progressive inching down of car ferry fares over a sustained period resulted in each case in a rise of traffic offsetting the reduced revenue per car unit. This is the sort of pattern to be followed if we are to see the breakthrough in numbers of passengers carried matching the rapid evolution of transport aircraft.

The problem for the airlines seem to be how to apply such a discipline when it looks as though the May 1957 forecast by Lord Douglas in "The Economics of Speed" — that the jet would be between 10% and 15% *more* expensive to operate per seat mile than an equivalent turboprop — may be vindicated by events. (See Table 4.)

air freight in the 1950's

I have always believed that air freight can and will be developed to a point at which it will become a direct challenge to other forms of freight transport — including shipping. A great deal remains to be done to streamline the whole system of air freighting and hitherto the rate of improvement has been all too slow. Up to the end of 1959, there was no aircraft in service that had been designed specifically for cargo. Reliance all along had been on adaptations of generally outmoded passenger aircraft with structural disadvantages which were millstones round the necks of all freight operators. Nevertheless the rate of increase in volume of air freight grew steadily, and we enter the 1960s with prospects of a definite breakthrough in the air freight business. The advent of specially designed air freighters such as the Canadair CL-44, the Britannic and the Argosy will, I am convinced, open up an entirely new era in this traffic and with each cent fall in rates new customers and new commodities of air freight will appear.

As proof of the growing awareness of the economic potential of air freight, one has only to look at the many practical and workmanlike studies of all aspects of air freight operations now appearing on both sides of the Atlantic. Aircraft manufacturers like Douglas, Boeing, Lockheed, Convair, Canadair, Vickers-Armstrongs, Shorts and Hawker Siddeley, and specialist air freight operators like Seaboard and Western, Flying Tigers, AAXICO, American Airlines and Slick, have all undertaken extensive studies and

TABLE 4

[FINANCIAL OPERATING RESULTS FOR ALL SCHEDULED AIRLINES, 1957, 1958

Description	1957 (US $ Million)	1958 (US $ Million)	1957-1958 (Percentage Change)
Revenues			
Passengers	$3,109	$3,256	+ 4·7%
Cargo	404	406	+ 0·5%
Mail	215	216	+ 0·5%
Charter	136	150	+ 10·3%
Incidental	107	94	− 12·2%
Total operating revenues	$3,971	$4,122	+ 3·8%
Expenses			
Flight operation	$1,219	$1,226	+ 0·6%
Maintenance and overhaul	771	812	+ 5·3%
Flight equipment depreciation	349	359	+ 2·9%
Other	1,673	1,710	+ 2·2%
Total operating expenses	$4,012	$4,107	+ 2·4%
Operating profit or loss	$−41	$+ 15	

Source: I.C.A.O.

I have had the opportunity of seeing some of these studies. It is encouraging to see that in almost every case they have dealt with the subject of air freight as a complete system calling for specialised aircraft and containers and a high degree of mechanisation at all stages of freight handling. (See Figure 3.)

The percentage of all freight movements which at present goes by air is almost infinitesimally small — of the order of 0.01% — so there is ample scope for increases which will enable rates to be cut to a point where air freight will rapidly become a major industry. It is worth noting that by October last year there were already 36 return transatlantic flights per week by all-freight aircraft of various airlines. These are in addition to the growing volume of freight carried as supplemental cargo in the holds of passenger aircraft. Lockheed and Douglas refer to freight as the Sleeping Giant.

A definite start has thus been made, and I trust that we in Great Britain will have the courage and good sense to ensure for ourselves a major share in this new industry, by support for the swing-nose Super-VC10. The Common Market Transall Consortium's C160 is the start of what could be formidable competition for us in the world's fastest income growing area.

1960/1970 — the coming generation

The air transport industry is poorly served in the matter of research and statistics, despite the fact that this is the basis for policy decisions. It was only last year that I.C.A.O. began to collect statistics on the origin and destination of passengers on a world-wide scale in an effort to find out why some people fly and why others do not. Thousands of millions of dollars of capital expenditure have been committed without any clear idea of what motivates people to fly. Information available in Europe is even less reliable than in North America. More economic research, better forecasting and better and more rapidly prepared origin/destination surveys are the hard facts upon which analyses, forecasts and decisions are based.

Perhaps the major imponderable in the coming period is to what extent airlines will continue to look for State assistance to tide them over the procurement decisions of recent years. At present it is undeniable that massive government support is common to nearly all countries' operations. Franchise taxes, for instance, are either waived or put at a nominal figure, hangars are sometimes let at peppercorn rentals, import duties manipulated to suit the airline, mail pay is often set at about twice the going rate which in turn is considerably above the freight rate, fuel taxes are often eliminated, special exchequer grants made arbitrarily for various purposes, airways are State-supported, airports are unremunerative, which means airlines are handled at terminals at less than cost, and special rates of compensation are paid to local service and helicopter operations.

There is not the research information available to make a forecast of subsidies, and anything in the

nature of specific figures can be little more than elaborate guesswork. Perhaps, therefore, a more notional or intuitive approach is the best way to see this uncharted region. There have been two airline recessions in the fifties: the United Nations in its 1959 report felt that in the absence of any explanation of the nature of inflation, and in the absence of evidence of effective monetary and fiscal controls, similar recessions must be expected in the sixties. After big wars there is always a boom, and any later depression could be as serious or more so than in the past in its impact on Gross National Products. If this is correct — and it seems reasonable — airline fortunes will continue to fluctuate during the sixties, and the rate of growth will, as I.C.A.O. foreshadowed, probably decline.

Perhaps the average gain will be between 3% and 8% until such time as a passenger breakthrough can be devised. This in turn does not seem possible without reappraisal of D.O.C.s and/or I.D.O.C.s and/or leg-room. No such prospect is on the cards even when the jetliners are re-engined with turbofan engines and even if they are re-engined again with second-generation fans. A breakthrough means that, instead of doubling the number of passengers in something approaching ten years, it would be doubled in between one and two years. To achieve something on this scale would require D.O.C.s to be halved. There is no prospect whatever of this being accomplished with any jet aircraft of any size or description up to 1970 — beyond which judgment must be reserved. Furthermore, the only sector distance where such a jump would reasonably be expected to yield the traffic is in the 350–400-mile region, and this is marginal for propellerless equipment. The curve of propellerless operating costs so often starts going up at distances below 1,000 miles, so whilst jets *can* operate at down to 500 miles such movements are only in effect possible if the city-pairs are highly lucrative, since they are nowhere near the lowest point on the D.O.C. curve, in spite of turbofans having a flat U curve instead of a sharp V.

As Mr. Masefield has already said, the sixties will possibly see the beginning of a divergence between very high speed at one extreme and very low costs at the other. But it seems to me that this would only get into its stride in the seventies.

The future success of the air freight industry depends on drastic reductions in the present rates, which in turn implies a streamlining of the whole system. The United States is a few years ahead of the rest of the Western world in spreading the gospel of air freight and in convincing potential users of its many advantages over other forms of transportation.

Already in the U.S.A. there is an example of a major railroad — the New York Central — investing some $6 millions in a specialised air freight operating company — Flying Tigers — with the object of integrating their activities as far as possible. There are also in existence practical schemes for door-to-door

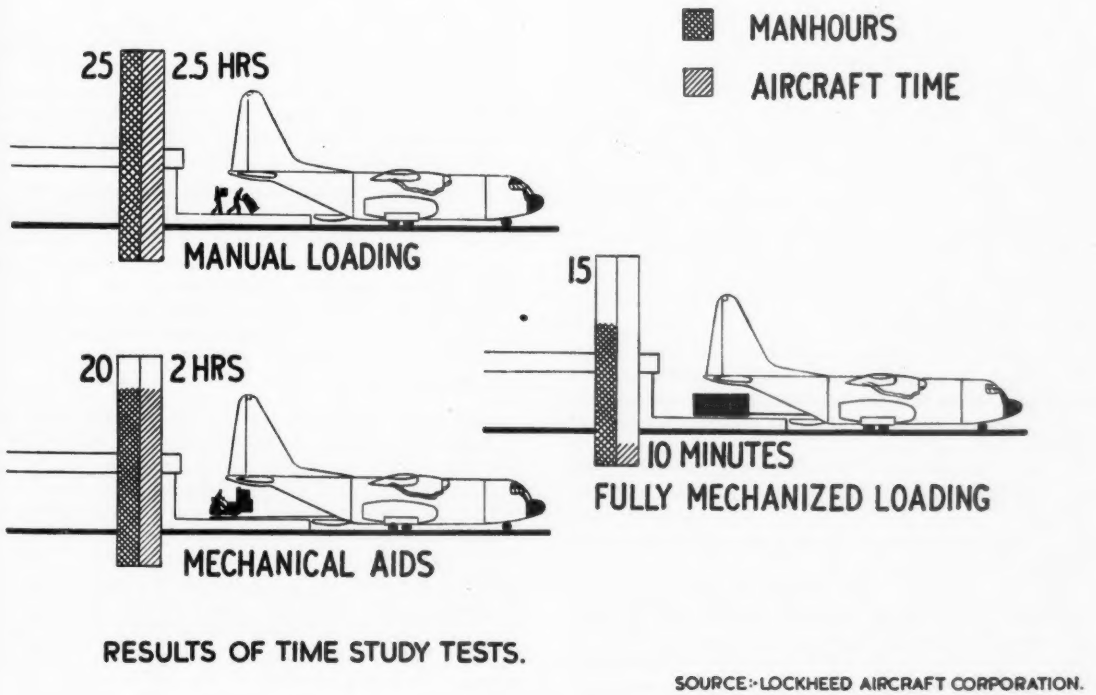


Fig. 3.

handling of air freight consignments and for through bills of lading covering two or more means of transport. In the U.S.A., the 1959 rates for domestic trunks averaged 23.74 cents per ton mile, while the all-cargo carriers got down to 19 cents. U.S. international operators' rates were 33.22 cents. By contrast, the European rates are much too high at an average of 36 cents.

Many of the freight studies already mentioned have attempted to calculate the possible gains by airlines and manufacturers of reductions in the rates of 50% to 75%. The validity of their findings depends, of course, on the formulae used. Short Brothers and Harland's study showed that cutting the tariff by a half from 36 cents to 18 cents resulted in a fivefold increase in ton-miles achieved. Cutting the rates two-thirds to 12 cents leads to a postulated twelvefold increase.

Bearing in mind that the theoretical capability of the Canadair CL-44 is some 4 cents per ton mile, Direct Operating Costs, the tariff of 12 cents is certainly feasible even assuming that Indirect Costs are 100% of Direct Costs. Indeed, it is theoretically possible for the CL-44 to offer a tariff of 10 cents which, on the Short formula, would imply a seventeenfold increase in ton-miles. This might result in a market for 250 aircraft of the CL-44 type. If a tariff of around 7 cents is assumed the increase would be about 25 times, and if this is a world-wide trend it is not difficult to see how Douglas arrived at a market of perhaps 400 swingtail DC-8s with a 3 cent Direct Operating Cost.

It is natural to ask whether there is a fallacy in all this. So little real progress has been achieved since 1955, when the Lockheed 1049H air freighter was introduced and seemed to promise appreciably lower rates with revenue rising from the greatly increased ton-miles that would be generated. Indeed, the rates went *up* from 17.1 cents to 19 cents in the period, and all that seems certain is that past increases of up to 100% in capacity payload have *not* produced any marked change. We can, however, hope that with the growing awareness of the potential of air freight as a major industry, the increase in payload of the CL-44 over the 1049H will produce a sharp-edged change of direction.

Mr. Emery F. Johnson, President of Air Cargo Inc., which represents 31 scheduled domestic carriers of air freight in the United States, said recently that " air freight is already a growing industry which will expand even more over the next few years. We in America jumped from 15 million ton-miles in 1946 to 595 million ton-miles in 1959. This year, with the advent of cargo DC-7s and CL-44s, we will boost air freight a further 15% and we will kick it up another 25% a year in 1961-62."

Future passenger and freight developments as outlined here have to be seen against two further performance limiting factors: the first of these is airport size and location. For a quarter of a century aviation has demanded from municipal authorities more *lebensraum* ten miles and often much less from the world's big cities than at any point in history. Airport sizes have been presented as at or even above the tolerable maximum in real estate. But the period has seen runways progressively lengthened from 5,000 feet and less to a recognised standard maximum today of 12–15,000 feet. At the main cities and world international gateways, 12–15,000 feet seems to be the limit of extension, and this time city authorities and governments seem to mean it. In future, supersonic transports must not only use the present runways, but use them in such a way that they make no more noise climbing out than the present subsonic jets.

If we are right in this, the present runway limits are the end, they could not go on extending indefinitely. A limit had to come and it has been reached. The corollary to this is that if jets and other overloaded planes are not allowed to use any more space than is currently laid out, or planned to be available, they should at the same time use all the concrete that has been provided.

This raises the issue of vertical or short take-off: nothing in life is free, and if a small ground roll is insisted on, it tends to be at the expense of cruise performance. It may be that the controversy is not so much on whether STOL is to be by banks of engines pushing downwards or a swivel jet lift-thrust, but whether STOL is worth it, when runways are physically available everywhere. Perhaps the future will lie in using STOL techniques not to produce short ground rolls but to lift more disposable load out of existing runways and so use the concrete that is there. Thus the long take-off and landing would be paradoxically by STOL techniques. Meanwhile, true STOL types seem limited to bush services where it is economically sound to pay a bit more for the aircraft in one way or another for the advantage of hacking a smaller strip out of the jungle or on a sloping ledge where every foot of runway is many times more costly than it ordinarily is.

The second performance limiting factor is in air traffic control, navigation techniques, precision separation and automatic flight. Instead of the usual procedure of assuming a supersonic transport and then engineering Air Traffic Control to accommodate it, perhaps a more realistic approach is rather to extrapolate current electronic and ATC techniques to 1970 and beyond and then fit the SST into the developing pattern.

Surely the goal is to use machines where they are superior to human computation, and to use the human brain where flexibility shows its economic superiority over a machine. A blending of these two forms of analysis should encompass three informational concepts — first for the aircrew, second for the controller and third for the military. With a discipline of this kind the three groups of people — pilots, controllers and military — can monitor relationships that are developing, rather than continue the familiar present *ad hoc* manipulation of traffic by fitting movements into each other in an arbitrary way.

The innovations which will give rise to this and, from a functional standpoint, admit the supersonic

transport and accommodate the progressive growth of IATA airline inventories are:

(i) the automatic ground-air-ground communication system — a fast date-link commonly known as AGACS, which will interrogate aircraft on a roll-call basis and provide rapid exchanges besides getting identification, position, altitude and distance from aircraft automatically;

(ii) a general refinement of existing techniques, with runway-gates to permit faster clearance of aircraft from runways, mobile lounges, better weather information at upper levels, fog-penetration lights and new radars;

(iii) automatic landing — something that has eluded aviation for five decades: now the outstanding difficulties are in process of being chewed up. There are about six systems in the world that are on a short list and one or more of these is likely to be selected before 1962 and these should be in service by the middle sixties;

(iv) is an assault on the one missing link in air traffic control measurements — which is altitude. Distance, bearing and now altitude are likely to be merged in a three-dimensional picture to take the guesswork and human frailties out of *en route* judgments.

All this is not going to be cheap to evolve but there is a military requirement for most of this information to enable fighters to sort out the sheep from the goats, since a surprise attack can come out of the blue and, without something to identify which aircraft have megaton weapons, enemy aircraft could hide among the airliners on the first day of general war. So the military with their great resources are providing the drive and money behind much of this work.

Thus it seems possible that an environment to suit the SST could be perfected before 1970 and, if so, the Mach 3 transport could be a reasonable proposition operationally.

Can it be a proposition technically? Though American manufacturers are apparently wholly self-confident, this surely is by no means a foregone conclusion. Some of us here advocate a more cautious approach and recommend a Mach 2 project as a sensible initial undertaking for this country. The amount of Mach 3 time by the world's test pilots at present is measured in minutes rather than hours — this speed attained and held for a few searing moments. Yet this is to be the speed that structures would soak in for two or more hours.

Structures predominantly in steel alloys would be built on a production-line basis where the number of all-steel aircraft in existence today can be numbered on the fingers of one hand. At a time when industry is only at the stage of evaluating one engine concept with another, service is promised in as little as six years. Industry maintains that this is not optimistic and it allows nearly twice as long to evolve the structure as it would take normally — the modern tempo seeing 250,000 and 350,000 lb. aircraft produced from start to service in as little as 3½ years (in the case of the Convair 880). Adding two to three years on to this time-frame to take care of the new problems is claimed as a reasonable allowance. Well, perhaps it is. But the present hurried development of three years has seen all four American turbine-powered aircraft run into trouble of some kind, and it would be unrealistic to expect that similar difficulties would not arise.

In previous generations of postwar aircraft, the commercial airliners not only came chronologically after the first bombers but were evolved in the wake of a whole concept of new military aircraft. The Stratocruiser, DC-6s and Tudors, for instance, came chronologically after the B-29, B-36 and the Lincoln. Similarly the Comet, 707, DC-8, CV-990 and Caravelle came after the B-46, B-47, B-52, Sperrin, the three V-bombers and the Vautour. Supersonic Transports, however, would be, if anything, ahead of the only military vehicle of comparable speed being sponsored, the B-70.

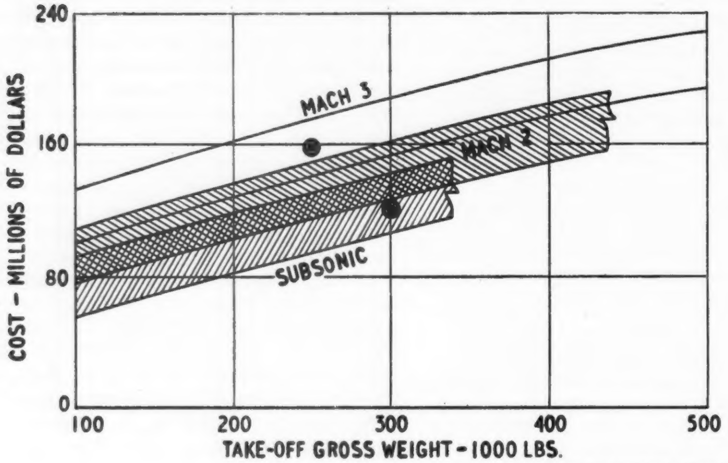
This break with tradition may succeed, but it does imply a risk and demands a tremendous investment in the SST by the airlines. Many of the airlines have become wary of the thankless task of pioneering aviation developments, but there is a group of them who are in the market for the SST either on their own account or as part of a consortium who will be pioneering with a vengeance. (See Figure 4.)

Britain is planning to start a supersonic transport, and this project is in line with Britain's history of being in the vanguard of progress on the prime class of vehicle, whether it be ship or aircraft. Not to pursue the supersonic transport would be to break with tradition. The arguments against doing it are well known: (i) that it would tie up too much of our industrial capacity, and (ii) big cities of the world are not big enough to justify more than a hundred or two of these vehicles. Naturally, it would be a consuming undertaking, but Britain cannot afford not to embark on it. The counter argument is to concentrate on aircraft designed to offer exceptionally low fares, but Britain clearly must do both since world traffic will be increasingly diverted into these two distinct paths — speed without regard for economy, and economy without regard for speed — and we cannot afford not to make a challenging contribution in both spheres if Britain is to remain a significant aviation influence. Since the advent of supersonic transports is now certain, either this country must design and build them or our airlines will be compelled to buy and operate foreign-built aircraft.

It has been a frequently held argument that the subsonic jets were chronologically about right — perhaps a shade early, for they might have been introduced with fans from the outset — and they would have served the traditional airline clientele. They then became workhorses through the absence of price competition, leaving service competition as the only outlet.

History must not be allowed to repeat itself with the SST else these will also be overbought — not to the same extent — and used on too many sectors that

ESTIMATED DEVELOPMENT COST



SOURCE: LOCKHEED AIRCRAFT CORPORATION

Fig. 4.

do not call for this type of service. Of course, it is impossible to say whether the closed IATA rate — either closed by agreement or closed tacitly — will continue through the sixties. The signs are that it will not be justified economically after a period, but who can say how successful a rearguard action against differential fare by aircraft type might be. If the inherently unstable economies in the capitalist countries result in a mild slump instead of a severe recession, it is possible that price competition would break out in several sectors of the world. In this case a valid alternative objective to the SST would be an aircraft for the low-income groups.

If this were to develop on any scale, it is possible that the history of first-class-tourist-economy traffic would repeat itself, but with the criteria being aircraft type instead of leg-room as one alternative, and then by different types of leg-room and service in the same class. Such moves might result in a galaxy of different fares, which is something that airlines seem to dread. But all one can say is that similar things have happened in other industries and price competition seems to improve the product, as well as widen the market.

If airlines want to widen the market in the sixties, they must expect a rough-and-tumble in which some people will get hurt. This process may be distasteful to airlines who are not used to it, but it is an accepted discipline in the marketing of products on Western principles, and if we believe in these principles we should be ready to invoke them.

1970/1980 — the future generation

Technological capability has been spiralling up and it would be ostrich-like to assume that this spiral will not continue. Research and development during the sixties will be devoted mainly to hypersonic aircraft and a small family of manned vehicles will be built capable of speeds above Mach 5. Some of them will be: (i) with breathing engines using the technique of supersonic internal flow; (ii) hybrid engines — ram-rockets and turbo-rockets; (iii) manned and unmanned satelloids that use power to maintain a low altitude orbit for a part of one circumnavigation of the earth.

The transport implications of this seem to be: (a) the relatively conventional turbofan-ramjet modified to use a supersonic flow; and (b) the invention of something that is not quite a satelloid. Just as a satelloid is not quite a satellite, so what will have transport potential is something that will not quite be a satelloid. It may owe some of its sustentation to Kepler effect like a space vehicle, but the rest of its trajectory will be governed by vehicle-induced lift.

Better use of the boundary layer will be a comparable development during the seventies when spadework for this has been completed during the sixties.

A recent Technical Press statement on the development of the SST stated: "The breakthrough in aerodynamics that makes the Mach 3.2 transport possible on a not prohibitive fuel consumption is the principle of compression-lift where, if the speed is high enough, the shockwave can be positioned so that the wing derives lift from the increased pressure behind the shockwave. Thus, once the SST is fast enough to ride its own shockwave, 90% of the thrust can be direct to propulsion." This is extremely technical but it does seem to promise practical, economic results from the research now being undertaken.

Also not to be forgotten in the sixties, seventies and eighties will be unspectacular improvement of known techniques. The pedestrian type of product will get progressively better: for a given power it will take more, weigh less, cost relatively less, burn less and fly faster and farther. Also it will be better designed and more astutely thought out. There is endless scope for refinement of existing engineering.

It seems possible that the seventies will see an end to the artificial restrictions of air transport that have plagued its first half-century of fulfilment. The sheer ubiquity of air transport will set its own rules of conduct, capability and participation. Once the sharp division of ways is reached between speed at any cost and economy at any speed, airlines will be free to find the lowest possible cost of vehicles by any means at their disposal. The possibilities opened out by this are limited only by the size of the world's population who at present do not fly. And this means virtually everybody in the world, for even now 90% of Americans do not use aviation habitually.

The stimulation to this will come as practical limits of the heat engine are reached in the seventies. This is likely to be a hard and fast fact, just as it was possible with the piston engine to see precisely how far this form of propulsion could be pushed. Considering that some aircraft now planned are capable of a 3 cent per ton mile direct cost and there should be time for about three generations of aircraft, it seems possible that a cent a mile tariff will be reached. A return fare of £1 10s. London/Paris is in a sense feasible now if passengers are allowed about 4 square feet, but a comparable fare travelling under more conventional conditions seems likely to evolve in the next two decades. I have already mentioned the possibility of a proportion of standing passengers carried at really low fares.

It should be the same thing in freight, as Grover Leoning has pointed out, in suggesting that a cargo aircraft of eight turbofans with a capacity payload of 200,000 lb. could match the work capacity of a rather large ocean-going fast cargo carrier, thus obsoleting these ships on a one-for-one basis. The ship can perform about 1,000 million short ton-miles and the aircraft around 1,250 million per year. (See Figure 5: Comparison of Dimensions.)

If freight aircraft of the size envisioned by Grover Leoning are ever produced, and whatever types of powerplant they might use, I am quite confident that they would be a direct challenge to cargo ships. They could, in fact, be designed to carry bulk cargoes never before considered as potential air freight, and to discharge through the equivalent of bomb bays or in detachable fuselage containers on the Fairchild Packplane principle.

I do wish to re-emphasise what I said earlier about aircraft utilisation. Nothing that the designers of aircraft, engines, airport terminals and freight handling systems can devise will be fully effective unless they all lead to a fuller and more economic utilisation of the passenger and freight aircraft themselves. The bigger and faster we build an aircraft, the more must we concentrate on eliminating every factor which impedes its turn-around time at airports. There will have to be an entirely new approach to the problem of handling large numbers of passengers and/or substantial quantities of freight. Customs and immigration formalities need drastic streamlining — especially in this country — if the present chaos at airports is to disappear. We used to think of 3,000 hours per annum as a reasonable utilisation for aircraft of the last decade. Already many airlines are averaging ten hours per day with each of their turbojet aircraft, and the figure could be higher if the aircraft could be turned round more quickly.

As a practical example of what full utilisation can achieve, the President of the American Flying Tiger line has stated that the fixed costs for the CL-44

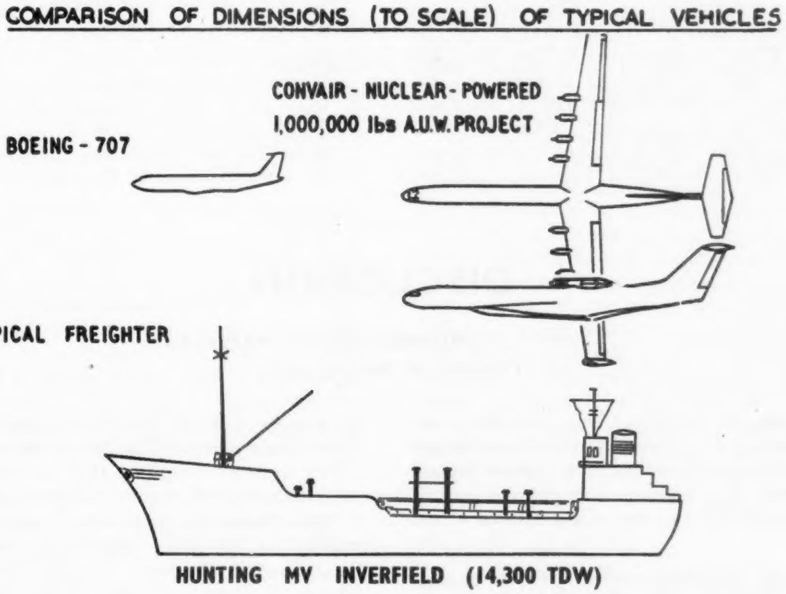


Fig. 5.

coming into service next year will be about $2,500 per day at a utilisation of eight hours per day. If the aircraft could be operated for up to fifteen to sixteen hours per day, the saving would be $162 per hour or $972,000 per annum. Thus, doubling utilisation would save 27.7% of the cost of the aircraft per year; or in other words, pay off the complete cost of the aircraft in a little less than four years.

1980/1990 — on the horizon

This decade may see consolidation of the seventies but using nuclear power, presumably fusion energy, and at the same time see commercial use of the cold engines, or so-called apparative jets. Electrical power may be supplied direct by nuclear source without the clumsy conversion units now necessary at all but the lower power levels. Beyond this, energy is either generated in the aircraft or perhaps passed to it by a wave, from a central generating source. Energy will be as plentiful and as cheap as water is now, and this advance will be used primarily in the air where power costs have always been so much at a premium. The General Dynamics Corporation of America are very well advanced in research along these lines and are studying propulsion through nuclear pulses and the direct conversion of heat into electric power. Before the end of this century, a great deal more is likely to be known about these and other subjects such as electro-gravitics and anti-gravity in relation to air and space travel.

Everyone agrees that universal common carrier locomotion is logically the air. But cost of providing the power needs has always been the stumbling-block. Once this drawback is removed in the era of limitless power, it follows that carrying everything almost everywhere by air will be an accepted fact. It has taken fifty years to make flying a technical commonplace and the rest of the century is likely to be taken up with putting aviation across. The century may be known for all kinds of achievements, but the 1900 to 2000 period will be aviation's century. In the twenty-first century aviation — or whatever word will describe it — will be as natural as walking is today.

I have tried to cover a great deal of ground in this Paper and I am fully aware that there are a number of gaps to be filled in covering subjects each of which would justify a complete Paper to itself. I am thinking of such things as general aviation — a new term covering all forms of business and executive flying; the developments in the Hovercraft and other forms of air-cushion-riding vehicles; the building of Monorail systems between city centres and major airports; and last, but certainly not least, Britain's place in space research.

I can only express the hope that, in all of these fields, this country will continue to use its scientific, technical and engineering skills to ensure and to maintain our rightful place among the world leaders in aviation and space research. This will, of course, call for the highest possible degree of leadership and statesmanship in our national policies. As I said at the beginning of this Paper, the record in this respect has hitherto been anything but encouraging, but I think that we are beginning to be aware of the importance and the possibility of British aviation being as flourishing in the days to come as British shipping was for centuries past. For the sake of her survival Britain must keep in the forefront of aerospace engineering. The alternative would be the possibility of handing over to the foreigner that which could and should be done here.

You will notice that I end this Paper with a piece of poetry. I think this particular piece of poetry sums up my own views on what this country has to try and do in the not-too-distant future. The competition with this country, whether we like it or not, in the next 10 years is going to be tremendous, and it is going to hurt, unless we pull our socks up. This piece of poetry is a way of asking people, I think, in some ways to pull their socks up from a poetic point of view.

The poem was written by Ella Wheeler Wilcox and is entitled " Achievement ".

" No man shall place a limit in thy strength;
Such triumphs as no mortal ever gained
May yet be thine if thou wilt but believe
In thy Creator and thyself: at length
Some feet will tread all heights now unattained—
Why not thine own? Press on, achieve! achieve! "

DISCUSSION

Chairman : **G. RONALD PRYOR, M.I.Prod.E.,**
President of the Institution.

THE **Chairman,** on behalf of the Institution, expressed thanks to The Royal Aeronautical Society for making their truly marvellous new lecture theatre available to them. The meeting place was, of course, particularly appropriate in view of the nature of the Paper.

The Paper had been instituted in 1955 to honour Lord Sempill, who was an Honorary Member and a Past President of The Institution of Production Engineers and, of course, a Past President and a Past Chairman of The Royal Aeronautical Society. They were all delighted that he was present to hear the Paper which was to be given in his honour.

The Chairman had much pleasure, therefore, in calling on Sir Percy Hunting to present The 1961 Lord Sempill Paper.

(Sir Percy Hunting then presented the Paper which appears on pages 237 - 250.)

Dr. E. S. Moult (*President, Royal Aeronautical Society*) opened the discussion by saying how pleased and honoured they all were to have Lord Sempill present. Indeed, this was a memorable occasion, because the Paper honoured someone who was one of the Institution's distinguished Past Presidents, and also one of the distinguished Past Presidents of The Royal Aeronautical Society.

Hitherto the series of Sempill Papers had been held at Southampton: by coming to 4 Hamilton Place the Institution was now at the very centre of aviation. The Paper was primarily for The Institution of Production Engineers, it had been given by someone with an honoured name in shipping and it was all about aviation. Thus, The Royal Aeronautical Society were being invaded on their own ground by another Institution who were telling them what sort of aircraft they should build! This was all a very good thing but the Society would certainly have to look to its laurels.

A little more seriously, he wished to say how much he found himself in agreement with what Sir Percy had said; so much so that he had little to add, and in any case there were others present who were better equipped to ask the proper questions. Sir Percy had posed the problems very clearly and very fairly. As they saw it, aviation was giving a very great service, but Sir Percy had very rightly stressed the need for more economic stability. It seemed to him that commercial success in aviation at the present time depended on a small margin between huge outgoings on the one hand and a huge income on the other. Unexpected variations in either, sometimes quite outside the control of the aircraft designer or operator, could upset that very delicate balance. Conversely, of course, relatively small improvements either in aircraft or in operational techniques could bring economic success.

As he saw them, the major problems before civil aviation today were, first of all, economic stability; secondly, safe operation in all weathers; and, thirdly, noise. Everywhere, the public were becoming increasingly noise-conscious. At the same time, aircraft speeds and sizes were going up, and this made things more difficult.

He had been interested in the author's comments on VTOL and STOL. A certain amount of nonsense had been talked in some circles about operating from city centre to city centre using vertical jet lift. He believed that noise alone would kill that. This kind of operation was properly the field of the helicopter, which could achieve a modest speed and was fairly quiet. He wished to ask Sir Percy whether he thought that operations from normal airports using numbers of aircraft with vertical or short take-off capabilities would make air traffic control problems more or less difficult.

From 1980 onwards Sir Percy had indicated some exciting possibilities. Those in the business found it was very difficult to foresee with any confidence beyond 10 or, perhaps, 15 years. With their noses to the grindstone things seemed to go very slowly, but in actual fact, because of the collective efforts throughout the world, major advances came much more quickly than we generally anticipated. He felt that many of the things Sir Percy had outlined might come sooner than had been suggested, but in what order and in exactly what form, one would hesitate to say. The great thing, from the British point of view, was that they had their rightful place in this coming activity.

In conclusion, he wished to thank Sir Percy for a very inspiring Paper, with its message to "press on".

Sir Percy Hunting, referring to the question whether he thought the short take-off would make traffic control more difficult, wondered whether they were not going the wrong way by producing an aircraft and then trying to get traffic control for that aircraft. Perhaps they should try to do the other things first, pressing on with traffic control so that as the aircraft came along they would fit into the pattern. The speaker had specifically asked whether short take-off would make traffic control more difficult. His own view was that it would not, if done properly, but he did not know enough of the technicalities to express an opinion and might easily be shot down over it. However, he would have thought there were plenty of means, mechanical and electrical, of traffic control which cost a great deal of money. If one was prepared to use that money to effect traffic control, then his answer to the question would be " No ".

Mr. Peter Masefield (*Managing Director, British Executive and General Aviation Ltd.*) endorsed the tributes paid to Sir Percy Hunting on his most controversial and stimulating Paper. One thing had impressed him enormously. Sir Percy, with all his great background of shipping and general administration in transport and in industry, had said quite flatly: " I see no alternative to an almost total preponderance of aviation over all other forms of transport." It was really a mighty statement from anyone with Sir Percy's background. He was sure that Sir Percy was right.

Although so much of what Sir Percy had said was right, if he himself might be controversial for the moment, he strongly disagreed with two things Sir Percy had said. One was that the airlines should farm out their maintenance. He believed that to be incorrect economic and engineering thinking. There was no doubt that although the two separate engineering edifices of the two corporations, B.E.A. and B.O.A.C., might have their critics and their faults—they had undoubtedly, in his opinion, led to great advances in the detailed technology of transport aeroplanes in Britain and had been very helpful to both the manufacturers and the operators. They had also, he believed, helped in another way. That was in quick turn-rounds — a point stressed by Sir Percy himself — because the maintenance was right on the spot and made possible concentrated effort to do the job efficiently and quickly.

He also disagreed with Sir Percy on the matter of leg room. As one with long legs he found even tourist class aeroplanes pretty painful, whereas in theatres he suffered acutely. In this lecture hall, also,

the audience might have some operational research to report on in relation to the 28 in. leg room they had been given. He personally felt that was an absolute minimum.

He felt, however, that Sir Percy might "have something" in his idea of "standing room only". In the First World War, horses had been suspended for transport from the roofs of railway trucks with a harness. He wondered whether some kind of harness could suspend passengers from the roof of an aeroplane so that operators could pack them in very closely. A spring attachment to the floor would probably satisfy the A.R.B.

He now wished to say something which was unpopular, because it tended to criticise the glamourised jets which were so attractive to everybody. He could not help feeling that in generations to come, air transport might be considered as "the industry which took the wrong turning" in the late 'fifties, when all the urge was for speed alone, instead of speed with economy. The big jets had achieved a great deal and had made possible important advances in the reduction of time between city centres on long distances—not so much on short ones. But, if they were objective and cast aside the mesmerism and the glamour, he thought that this reduction in time and long ranges had been achieved at a sacrifice of four things: they had certainly sacrificed runway economy — and not at cost to the airlines. Communities had been put to enormous expense (which had not been passed on to the airlines), in putting down much larger runways. Secondly, if they were honest, they would have to recognise that some degree of safety had been sacrificed in the fact that higher approach speeds than ever before were now accepted. Some jet aircraft were also quite critical at take-off. And this had occasionally brought trouble. There was undoubtedly some sacrifice in safety there, though it was unpopular to say it.

Then they had certainly, in his view, sacrificed cost. There was undoubtedly an increase in specific operating cost, although it was disguised by the much larger size of the large jet aircraft compared with earlier types. They had also sacrificed some of the comfort of people living near airports as a result of increased noise.

The jets had brought speed. But he believed that they had brought it at a heavy cost, most of which was hidden and not properly appreciated, largely because of the great increase of revenue they had also brought about. He sincerely believed that if the airlines had gone the other way in the 'fifties and emphasised lower cost, and had urged manufacturers to produce aeroplanes which would be less expensive to operate, then the public would have been able to fly today at about 20% lower fares than existed.

Sir Percy had referred to the requirements of "leaner engines coupled with lower air speeds". He believed that this was one way towards economy. Perhaps the Vanguard and the CL44 would show indications in that direction, provided that the I.A.T.A. regulations would permit lower fares to be charged.

There was no doubt, of course, that the jets were glamourous. They might be compared, he felt, to living with a film star. Very beautiful to look at, very great fun to live with (at least, he imagined so), very high income earners. But oh, what they cost to take about and how wearing they were to keep up with! And now they had the even more glamourous (and more noisy) and probably more costly, supersonic transport coming along. There was a place for the glamourous jet. But he wished, also, to make a plea for the more humdrum, low cost, aeroplane, which would bring down costs substantially, and for a more flexible outlook by I.A.T.A.

In conclusion, he would like to ask Sir Percy what he felt was the future of shipping in the era they were now entering, in air transport and in other directions? How did he feel that the great shipping companies could best contribute to the world in which they now lived? Finally, he wished to compliment Sir Percy on being the first person he knew of to bring Ella Wheeler Wilcox into an aeronautical gathering. He had now learned the origin of the phrase: "Press on regardless".

Sir Percy Hunting said that he anticipated trouble over his remarks concerning maintenance at London Airport, and judging by a certain Sunday newspaper, he wondered why the two corporations had not disintegrated by now. He would have said there were arguments on both sides, but he had always felt that if one had smaller units in engineering or in anything, if they were properly run they were more efficient than the larger units. That, he knew, was open to argument and controversy, but if a thing were put out to contract, very often by necessity one arrived at the position where the contractor had to be so efficient that he would explore every new method, otherwise he would go broke.

He was not saying for one moment that the engineering side at London Airport was not highly efficient, but it could not go broke and that possibility of going broke, he felt, was a necessary spur in keeping very much abreast of the times.

With regard to leg room—and the suggestions about harness, too—he thought they ought to consider the Underground in the rush hour. It was chaos and had been for years, but people put up with it. Those who did not like it hated it like poison, and he knew plenty of people in his own organisation who just had to put up with it. They did not like it.

He was just wondering, therefore, whether enough thought had been given by the industry to this question of leg room; and while he was on the point, he knew that a terrific amount of money had been spent on designing seats but he did not think they had got the answer yet. He wondered whether they could use other materials; whether they could make seats lighter and by so doing enable operators to carry more freight or more passengers. He still thought there was a tremendous field for investigation of the seats they used. He was personally quite serious about the harness business. If people were prepared to travel in great discomfort for half-an-hour or so on the Underground, why should they not cross the

Channel hanging on to a form of harness? It was not long ago that he had crossed the Channel, going from London Airport to Paris, in a Caravelle and from take-off to touch-down it was 50 minutes. He believed that in the next 10 years it would be reduced to 30 minutes. Why should people not stand for 30 minutes, as they did in the Underground? He had no doubt that the A.R.B. would have a few headaches, but why not? That was what they were there for.

Then there was the question of speed in relation to lower cost. Again, one could argue that sort of thing for a very long time. Undoubtedly a generation was growing up—their children, and in his case, his grandchildren—who were used to the speed of life in 1961, and the idea of taking a little bit longer to travel from A to B by a slower aeroplane might not appeal to them much if they could afford to do otherwise. In his opinion, if they could afford it, they would always go by the speedier aeroplane. He agreed that they might be able to achieve a form of mass flying by the slower aeroplane, but he wondered whether the way to try that out was not first by the short haul method to see whether it worked.

Mr. Masefield had asked what he thought of shipping at the moment. He believed that ships would go on and that they would make money, but in time the aircraft would go more and more and more into shipping. He might be sticking his neck out here, and for a shipowner to say it was, of course, heresy, but he thought that by the end of the century the aircraft might have taken over in a great many operations that were done by ships. His reason was this. The motor car, the railway, the pedestrian, and animals—except the birds—had to stick to the surface of the earth. That was not so with the aeroplane, which got off the surface of the earth and could fly from one spot to another, doing this—theoretically, at any rate—in one hop. But a ship, or any other form of surface transport, came to the end of its journey at a certain spot—the coast, for instance—and then had to unload and discharge in one form or another, whether it was to a ship or a railway train or a piece of road transport. That meant that several operations had to take place—perhaps by train, by ship, and by train again—whereas the aeroplane could do the job much more efficiently in one go, and for that reason he thought that the aeroplane, especially as it got bigger and better, was the thing that was really going to hurt shipping.

One point which had occurred to him during the discussion was whether railroads would ever be built in under-developed countries. Would not the aeroplane take the place of railways there? Certain of the hovercraft probably could. Would the St. Lawrence seaway pay for itself—remembering that it had 50 years in which to do it? Would not the airlines put it out of business in the next 30 years?

About three years ago a special railroad had been built to ship iron ore from one of the largest strikes of iron ore in the world, in Labrador. The railroad was 360 miles long and cost $225,000,000. The equivalent air distance was 320 miles. He wondered whether that railroad would ever have been built if they had had a 1,000,000 lb. all-up weight aeroplane, or a 1,000 ton hovercraft. He hoped that that had answered the question as far as possible.

Mr. R. E. Mills (*S. E. Opperman Ltd.*) was disappointed not to hear Sir Percy talk about the actual cost of aircraft. He thought that the modern sophisticated production methods that were used in the manufacture of aircraft—certainly during the War—had been exploded by a company with which Sir Percy had quite a lot to do, and he had expected him to talk on this point, especially to The Institution of Production Engineers.

With regard to Mr. Masefield's remarks he wished to point out that—if he was not being too nationalistic—the Bristol Aeroplane Company, as it was known at the time, was possibly more responsible for the introduction of the freighter aircraft into the world than any company mentioned in the Paper.

Sir Percy Hunting admitted that perhaps it was an omission on his part. He had rather kept off the cost of aircraft because he had not thought the title of the Paper justified it. Under the heading "Scope of Paper" he had said: "The theme originally suggested to me was 'The World's Future Transport Requirements', designed to cover both 'The Transport Industry's Requirements' and 'The Manufacturing Industry's Proposals'. Although I have had some direct association with the aircraft industry, this has been confined to the manufacture of light training aircraft." He felt sure that there were plenty of people present who used slide rules and drew wonderful things on squared paper and would be able to answer the question far better than he could.

Mr. Jack Hood (*Consulting Engineer*) congratulated Sir Percy on a really wonderful Paper, full of technical matter that wanted some digesting but was nevertheless true. Mr. Hood wanted to see the more practical side discussed and would like to see more attention given to the problem of economic rate for the day-to-day commercial as well as passenger traffic instead of this business of getting to Mars and the moon, where as far as was known there was no one there yet to make use of our merchandise and talent.

Did Sir Percy, or for that matter Lord Sempill, know that on 30th January there was a Bill going through the House of Commons concerning the revision of rates for transport charges, to see if they could be reduced? On the Committee concerned would be representation from British Railways, the L.T.B., docks and waterways shipping industry and so on, but no mention of B.O.A.C. or in fact any of the air transport organisations.

Perhaps Sir Percy would see, now he had a little time to spare, if he could break in on this set-up. Anything that could make for better facilities for more economic transport by air would be in everyone's interest. The old-fashioned methods by the civil servant in our Customs could certainly be improved, and there was need for a better system to turn round

at the various air terminals to get goods and passengers to their destinations more quickly. It was no good chopping a few hours off a trip if it was lost through standing around waiting for Customs clearance.

Regarding types of aircraft and suitability, we had got to provide what the customer wanted, both for passenger and freight. More co-operation was needed here.

Mr. Hood said he was most impressed by the figures Sir Percy had quoted, which indicated that anyone interested enough could make use of these figures to plan for the future. Action must be taken quickly before Britain lost her lead in this important new field of transport.

Mr. Hood said he would like to see the use of the helicopter for both freight and passenger traffic, developed on a bigger scale, and when the new B.O.A.C. service started in March, giving a 707 Boeing jet twice a week from London to Los Angeles in 12 hours, another step in the right direction would have been made.

Sir George Edwards (*Managing Director, Vickers-Armstrongs* (*Aircraft*) *Ltd.*) suggested that the solution to the problem of packing in the passengers was easy; all one had to do was to give them an injection and stack them horizontally together with the cargo. That also had the advantage of preventing them from worrying about the 55 seconds on the ground becoming a minute-and-a-half and not getting off at all. It was an entirely manageable solution and involved no slings or straps or anything else; and nobody knew he was missing the champagne and caviar which he could not do without when he was on an expense account. That was solution number one to the close seating and standing up problem.

He had thought Sir Percy had looked in his direction when he said he was not in a very good position to talk about aircraft manufacturing costs, because he had passed on to one or other of them his responsibility in that particular field; but, without going into a dissertation about the cost of aeroplanes, he could say without any hesitation at all that there was not a manufacturer of big civil aircraft at the present time on either side of the Atlantic who would not be absolutely delighted to sell all the aeroplanes he was making at what it cost him, as distinct from what he could get for them.

Sir Percy, as those who knew him well could expect, had written a Paper that was a mixture of commonsense and courage. He knew that Sir Percy had in him more than the normal quota of wisdom and he would like to have some of that wisdom handed back in order to supply the answer to three problems. Sir Percy had advocated, rightly, a process whereby an aeroplane had to be produced which could achieve the lowest seat mile cost. How did he reconcile the situation with the persistent attitude of the airlines, whose executives said: "Do not worry me with the fact that your aeroplane has a lower seat cost than anything else. If I put it on the routes with propellers on it I cannot fill it."

They had to remember that it was part of the salesmen's job to fill the seats and they used all the necessary glamour in order to do it. The result was that the chap on the factory floor who would like to go to France for a holiday was unable to do so because he was unable to afford it. He (Sir George) was simple enough to believe that as long as they had the present fare structure and the present approach to traffic they would not get the ultra cheap aeroplane that they wanted. The aeroplane would be filled solely on the basis of the "pitch" that the salespeople in the airline made at their management about selling seats, regardless of what they cost to operate.

No one would know whether the great freight market that had been talked about was actually there until some airline or other had invested enormous capital in the equipment, both airborne and on the ground, which was necessary in order to find out direct operating costs. No less than three major airlines had already said to him: "This is a jolly good idea for somebody else to find out, because if they have got it wrong, they go broke." He would like to have heard something from Sir Percy on that problem.

Then Sir Percy had referred to the supersonic transport situation, but he thought that the airlines would have as much as they could manage in going at twice the speed of sound, as distinct from three times. Sir Percy knew as well as he did that commonsense would not prevail in this, and that the thing that would really settle it was known as "prestige". If the Russians showed the slightest signs of doing it then they would have their aircraft at Mach 3, 4 or 5. They would be thrust down the airlines' throats, regardless of whether they could afford them, or whether they were safe or anything else. He would like to ask Sir Percy how that situation could be prevented.

Sir Percy Hunting thought that one would need the wisdom of Solomon to answer that question. He believed that seat mile cost at present among the airlines — and this observation could be dynamite — was to a large extent fictitious. There was a certain body called I.C.A.O. He repeated that a lot of seat costs today were literally fictitious.

Again, coming back to shipping, in his father's time and in his grandfather's time competition was wide open; it was "dog eat dog" and they either lived or went broke. Not an awful lot of airlines went broke. Some of the independent ones did, but a lot still lived, and that was a fictitious situation. If they had a "free for all" — and it might take some years to do it — they would eventually, he thought, get down to what he called an economic price for selling transport. Anyway, that was one answer.

With regard to freight, he had given, he thought, a reference to increasing the ultilisation of an aircraft to 10 or 12 hours per day or something like that. Why should not that be more? The reliability of a jet today was, say, fixed at 12 hours. Why

could it not be put up to 16 or 20 hours? The aircraft relied on speed plus a certain amount of weight carrying, but as soon as it was on the ground it seemed to lose everything to do with speed. Why? Again, this could be dynamite.

To take their friends the Customs — and this was not going to be a tirade against a fine body of people — if he remembered his history rightly, the Customs were started in the time of Charles II as a protection for the revenue. Unfortunately, the particular statute had been interpreted in the same way for 300 years. Why? Was it not possible to streamline Customs to the aeroplane? With a ship or a railroad one had a little bit more time, but the aeroplane had not any time to waste. If an aeroplane could fly 24 hours a day that would be fine, but it could not; he knew that; but why should they have to put up with the terrific amount of paper work involved in Customs? There were many things coming from abroad that were going straight on and did not need opening at all. Why did it take three days to clear? That was utter nonsense. He made that comment as a private individual.

The point about an aircraft was its speed. One arrived from somewhere or other at London Airport and got into a bus which took one to a ramp, one walked up that ramp, waited in a waiting room and then went through Customs, eventually getting out. In the meantime the baggage had been loaded and taken into the baggage room and sent up on an endless belt, but all that took a terrific amount of time, and he would have thought that they should really use speed there. Unfortunately, they did not use it, and he would have said that applied in some way with regard to freight

He believed that the question of producing the right aircraft was a very difficult one and would be extremely costly, but he was wondering whether they had done enough thinking about this particular project.

He also thought that it should be possible to have perhaps better liaison between the airlines and the manufacturers. He could hear people saying they already had that liaison, but he was prepared to argue about that.

With regard to supersonic air transport, frankly, he just could not express an opinion, but he was pretty well sure of one thing: that whether the Russians did it or not, somebody had got to do it, and if Britain was not in that race in some way, then it would have to buy foreign aircraft or go out of business in that field. That was all he had to say on that matter.

Lord Sempill expressed his gratitude to the President for the honour conferred upon him and the privilege of asking Sir Percy to accept, on behalf of the Institution, a permanent memento of this great and interesting occasion. It was a piece of silver which would support a nice quantity of that best drink of all, the water of life in Scotland, together with half-a-dozen glasses. He hoped that

Sir Percy Hunting (left) receives from Lord Sempill an inscribed silver salver as a memento of the presentation of The 1961 Lord Sempill Paper.

Sir Percy would place it on his sideboard where he would always have it as a memento of the occasion.

As the splendid contributions to the discussion had emphasised, this was a remarkably interesting and thought-provoking Paper. It would be with them for a very long time. But, long after he had forgotten all the questions that he had been asked, Sir Percy would have this memento on his sideboard, and he would be continually drinking the health not only of the speakers but of The Institution of Production Engineers!

Sir Percy had concluded his Paper with a quotation from Ella Wheeler Wilcox, and Lord Sempill now wished to carry him back at least a century-and-a-half to a famous English writer of that day who had foreseen something of what Sir Percy had been telling them. He had written: "I have long been of the opinion that, instead of the tardy conveyance of ships and of chariots, man might use the swifter migration of wings; that the fields of the air are open to knowledge, and that only ignorant and idle people crawl along the ground.' That was exactly what Sir Percy wanted them to do—get up into the air—and they all congratulated him.

Sir Percy Hunting (in reply to the presentation) thanked Lord Sempill and the members of the Institution for a very wonderful souvenir of the occasion, and assured them that he had the right type of liquid. As a mere Sassenach who had been to school in Scotland, though before Lord Sempill's time, he could not recall having learned to drink Scotch whisky at school, but he had certainly done so after, and still liked it. It was a wonderful gesture on their part and he assured them that their gift would certainly have an honoured place on his sideboard.

The meeting then concluded.

EXPERIMENTAL INVESTIGATION OF THE EXTRUSION OF METALS

by H. Ll. D. PUGH, B.Sc., F.Inst.P., F.I.M.,

and M. T. WATKINS, B.Sc., A.Inst.P.

Mr. Pugh graduated with a First Class honours degree in Physics at Swansea in 1935, and later took a First Class honours degree at London.

In 1939 he joined the Road Research Laboratory (DSIR) where for a good deal of his time he was engaged on armament research, particularly on the design of special armaments, and on the resistance of metals and concrete to projectile and explosive forms of attack.

In 1948 he was appointed to the new National Engineering Laboratory (DSIR) as head of the Plasticity Division. This Division is engaged in high-pressure research, research on the plastic properties of materials, and on formation and machining processes.

Mr. Watkins took an honours degree in Physics at the University College of Swansea in 1939 and served with the Royal Engineers from 1940 to 1946.

For four years he worked at the Research Department of W. Jessop & Sons Ltd., Sheffield, ultimately as Senior Research Physicist.

He joined the staff of the National Engineering Laboratory in 1950 and is in charge of the Formation Section working on problems of extrusions and forgings.

EXTRUSION is essentially a process in which a billet or slug of material is converted into a continuous product of uniform cross section by forcing it through a suitably shaped die. By the use of appropriate tooling, the metal may be formed into rod, tube or can, the length of the product depending on the dimensions of the initial billet, but in all cases the cross-sectional area is significantly less than that of the initial billet. Compared with most industrial methods of forming metals this is a comparatively recent innovation which is now firmly established as one of the more important metal working processes.

The earliest use of the process of extrusion is ascribed to Bramah of Sheffield who in 1797 described the process for making long pipes of lead for the distribution of beer. This led, in the first half of the 19th century, to the design and construction of hydraulic presses for the extrusion of lead pipes and sheet, and this was followed in the second half of the century by the further development of pipe presses incorporating heated chambers, and the use of hydraulic accumulators.

By the middle of the 19th century, the extrusion of lead was firmly established as a process. In 1897 Borel in France and Wesslau in Germany suggested an efficient method for extruding lead directly on to cable, and this gave a tremendous impetus to the development of extrusion as a process.

The application of this process to metals other than lead was delayed partly by the mistaken idea that other metals did not become "sufficiently plastic" at room temperature and that it was necessary to heat these other metals up to quite high temperatures, e.g., 600°C in the case of brass; whereas the main difficulty was, as it is now appreciated, the limited press capacity. Indeed, the conception of insufficient plasticity persists to some extent even today, and partly accounts for the delay in the introduction of the cold extrusion of steel.

The success of the application of extrusion to the hot working of metals, other than lead, is due largely to the work of Dick, who in 1894, produced a design of press which successfully solved the major difficulties of hot extrusion.

Cold extrusion seems to have started in America about the turn of the century, by the introduction of a so-called Hooker process, which in actual fact was developed by Lee. This rapidly became an established process, due to the success in making cartridge cases, toothpaste tubes and zinc condenser cases.

It was not until the 1920's that the cold extrusion of steel was first investigated in Germany, but developments in this field were not rapid until the introduction of phosphate films to act as a lubricant carrier in the mid 1930's. These developments were kept secret because of the importance of this process in the manufacture of arms. However, by 1942, a process was being used on a limited scale in the U.S.A.

The rapid development of the process of extrusion is mainly due to the advantages which it can offer; it can produce products of a greater diversity of sections than almost any other mechanical working process, and it is ideal in cases where lengths of uniform section are required. This diversity of section can be produced in a single machine with relative ease, namely by changing the die. Cold extrusion can give, in a rapid and economical manner, a wrought product with good mechanical properties and high dimensional accuracy, in which machining operations are minimised or eliminated with consequent material saving, and having an excellent polished surface, e.g., in the case of aluminium.

As in the case of forging, extrusion has been used in two main ways; firstly to break down the "as cast" material into wrought forms, and secondly to convert wrought semi-finished products into finished engineering components. In the primary process, billets varying from 6 in. to 20in. diameter are extruded in horizontal hydraulic presses of large capacity, normally in the range 1,000 to 5,000 tons, and at moderate ram speeds. This is traditionally a hot working process, billets being fed from the furnace into a heated chamber. In the secondary process, slugs are cropped, blanked or machined from wrought bar or strip, and extruded into finished components in both horizontal and vertical presses mainly of the mechanical type. The size of product is significantly smaller and the slug is not usually heated. This process is known as impact extrusion.

The tendency in the past has been to study each aspect separately, whereas the basic principles of extrusion are equally applicable to both. The investigations undertaken at the National Engineering Laboratory cover both aspects of extrusion, in an attempt to obtain an understanding of the mechanics of deformation of metals during this process.

experimental procedure

In order to secure a more rigid control of process variables and greater flexibility in use, most experimental work on the extrusion process has been carried out on a laboratory scale using suitable sub-presses.

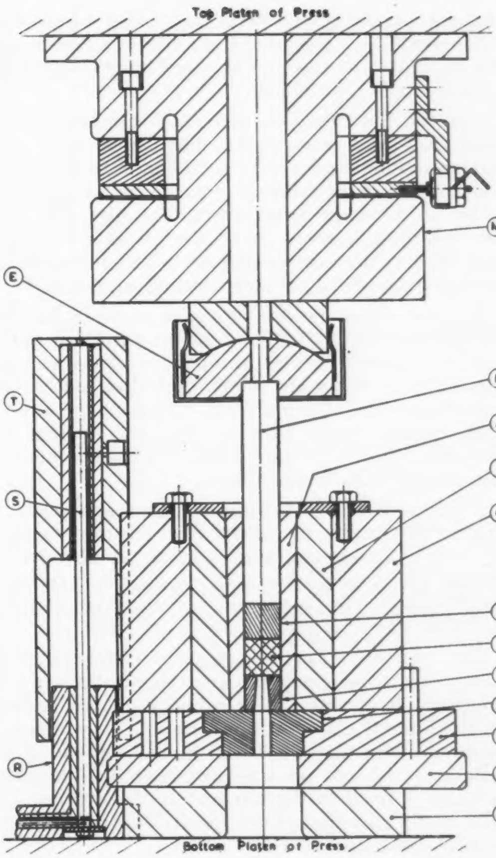


Fig. 1. Instrumented apparatus for carrying out experiments on extrusion.

A variety of sub-presses has been developed for the extrusion of metals both at room and elevated temperatures. These can then be mounted in the appropriate hydraulic or mechanical press as required.

A typical sub-press for the cold extrusion of metals is shown in Fig. 1. This consisted of an inner liner A of a 1.0%C, 0.75%Cr, 0.85%Mn, and 0.40%W, tool steel shrunk into an intermediate cylinder B of steel to B.S. En26 in the fully hardened condition, which in turn is a push fit into an outer cylinder C. The die F located within the bore of the container was supported on a tool steel insert G carried in the slide plate H which was forced against the base of the inner cylinder by the wedge plate I, provided with a 1° taper and carried in the slotted base J. The plate H could move in the slot and its position located by a stop pin. The insert was provided with an aperture in the shape of a key hole; in the extruding position the die was supported on the shoulders of the slot, but in the ejection position the die could pass through the circular hole.

In forward extrusion the billet K was inserted into the container followed by the compression disc L

and the punch D, the press load being transmitted through a spherical seating E. For backward extrusion the die and compression disc were interchanged and a hollow punch provided.

For the hot extrusion of metals substantially the same sub-press was used. The inner liner and intermediate cylinder were surrounded by a heating coil and the outer cylinder replaced by an insulating jacket to minimise heat losses. The dies and compression discs, however, were made from a 2.85% Cr, 10% W, 0.35% V hot working steel. This sub-press has worked satisfactorily at temperatures up to 550°C.

In most investigations provision is made for continuously recording the load on the extrusion punch and the punch travel throughout the extrusion process using either electronic, optical or mechanical instrumentation. During each extrusion operation a characteristic curve can be obtained relating the extrusion load to the punch travel or displacement of the billet within the chamber.

Typical electronic instrumentation is also shown in Fig. 1. The load cell, mounted on the top platen of the press, consisted of a steel block M of the form shown. The load produced an elastic compression of the block which was measured by the change produced in the air gap of a parallel plate condenser.

The punch or ram movement was measured by means of a stroke gauge mounted in parallel with the sub-press. It consisted of a cylindrical base R fixed on the bottom platen of the press and in which was mounted an insulated cylinder S. The top end of the cylinder fitted into the insulated bore of a movable cylinder T fixed to the top platen of the press, and thus produced a change in capacity depending on the relative movement of T.

The load cell and stroke gauge were used in conjunction with appropriate amplifiers and C.R. recording equipment and the load, stroke and time records of the extrusion obtained on 70 mm film.

The plastic deformation of metals involves irrecoverable strains and the work of deformation appears largely in the form of heat energy. Considerable increases could thus occur in the temperature of the billet during extrusion at room and elevated temperatures and a knowledge of their magnitude is essential to the understanding of these processes. For many practical purposes, this heating effect may be unimportant but in other applications the effect on the properties of the product and on the mechanics of the deformation may be marked, as in the occurrence of hot shortness. A technique has been developed for the recording of temperature rises at points within the billet throughout the extrusion operation.[1]

The manner in which metal flows during extrusion is also of considerable importance and two methods are extensively used to study this aspect. In the first, billet and partially extruded product are removed at the appropriate stage, sectioned, etched, and visually examined. In the second, the billet is split along the diametral axis prior to extrusion and a square grid is scribed on the parted face. The two half billets are inserted in the chamber, the operation stopped at the required stage, the billet withdrawn and opened along the parted face for examination. This has the added advantage that both qualitative and quantitative studies of metal flow can be made. The patterns obtained by both methods show the accumulated effect of metal flow from the beginning of the extrusion to the stage at which it is interrupted.

Whilst the precise effects of many of the factors which govern the extrusion of metals are becoming increasingly known, further studies are necessary to ascertain the extent to which these effects are consistent in the extrusion of a large range of materials or of a range of compositions of one material, e.g., aluminium and its alloys. The effect of any single factor on the extrusion of metals has been assessed from results of tests in which only that factor is varied. This assessment is usually based on a comparison of the basic punch load-travel curves and of the flow patterns before and after the factor is varied. It is tacitly assumed that the factors are mutually independent and are not complicated by metallurgical considerations.

TABLE 1

Composition and heat-treatment of aluminium 99.5% purity and aluminium alloy DTD363

Material	*Fe*	*Cu*	*Si*	*Mn*	*Mg*	*Ti*	*Cr*	*Zn*	*Al*	*0.1% Proof Stress*	*Tensile Strength*	*% Elongation*
Aluminium 99.5%	0.27	0.01	0.11	*Tr*	—	—	—	—	REM			
Alloy DTD363	0.38	1.91	0.20	0.20	2.40	0.05	0.12	7.20	REM	38 tons/in.^{2}	41.6 tons/in.^{2}	7

Aluminium 99.5%
Anneal: 1 hour at 350°C
Hardness: 21 HV5

Aluminium Alloy DTD363
Anneal: 2 hours at 380°C and cool slowly
Hardness: 60 HV5 in annealed condition
Solution treatment: 2 to 4 hours at 455 to 465°C, quench in water
Ageing treatment: 4 to 8 hours at 130 to 140°C
Hardness: 190 HV5 in fully heat-treated conditions

hot extrusion of aluminium, 99.5% purity and aluminium alloy DTD363

Aluminium and its alloys have been successfully hot extruded since the beginning of this century. The requirements of the aircraft industry have resulted in the development of very high strength aluminium alloys which presented many problems before being successfully extruded. Pearson[2] reported that all metals were liable to cracking from hot-shortness when they were deformed at excessively high temperatures. Smith [3] indicated the problems encountered in the hot extrusion on an industrial scale of the heat-treated aluminium alloys. He stated that the best method of retaining a fine grain structure in the heat-treated product would be to ensure recrystallization during extrusion. This was not always possible since the recrystallization temperatures of some alloys were well above their practical extrusion temperatures. At a lower extrusion temperature, a correct balance of speed and temperature was required since some degree of strain favourable to grain growth would be present.

The temperature at which a metal can be extruded ranges from a minimum at which the press capacity is just sufficient to extrude the metal to a maximum at which failure occurs. For aluminium 99.5% purity, failure would not occur until the temperature was close to its melting point but, for certain alloys, e.g., aluminium alloy DTD 363, metallurgical changes in their structures could lead to earlier failure. The successful extrusion of such alloys on an industrial scale is often only achieved within a narrow temperature range.

A study[4] was undertaken to determine the conditions of extrusion ratio in the range 1.2 to 50, ram speed in the range 0.4 to 30 in./min. and initial billet temperature in range 20°C—400°C leading to failure by hot shortness of products extruded from billets of aluminium alloy DTD363. The behaviour of the alloy was also compared with that of aluminium 99.5% purity extruded under the same conditions. The composition, heat treatments and mechanical properties of these materials are given in Table I.

Cylindrical billets of 0.990 in. diameter and 1 in. length in the annealed condition were extruded in a sub-press mounted in a 200 ton hydraulic press, having an upstroking ram capable of speeds up to 30 in./min. The billets were heated in situ in the extrusion container, both being held at the same temperature prior to extrusion.

(a) effect of reduction and initial billet temperature on the pressure required to extrude rods

Typical curves for the forward extrusion of rod from billets of aluminium 99.5% purity at 20°C and 400°C are shown in Fig. 2. Initially the metal is compacted until it fills the extrusion chamber and then is compressed at increasing load until the rod begins to flow through the die. It will be noted that the manner in which the load builds up and subsequently varies with increasing displacement of metal is particularly dependent on the initial temperature of the billet.

The maximum pressures required to extrude rods at extrusion ratios ranging from 1.23 to 200 for aluminium 99.5% purity and from 1.23 to 50 for the alloy

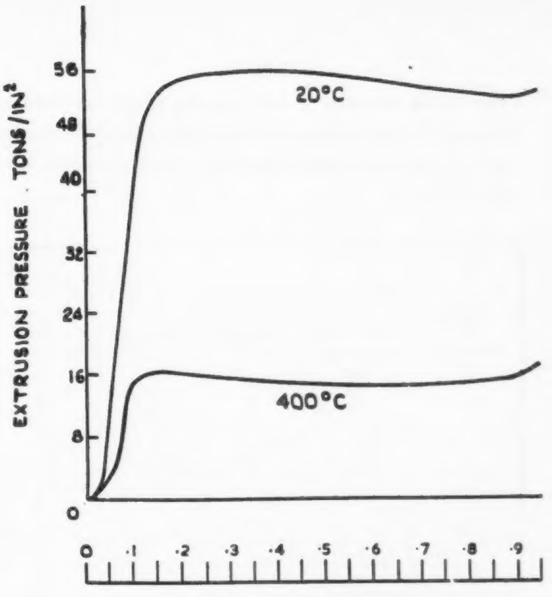


Fig. 2. Typical extrusion pressure — ram displacement characteristic for the extrusion of rod in aluminium 99.5% purity at 20°C and 400°C.

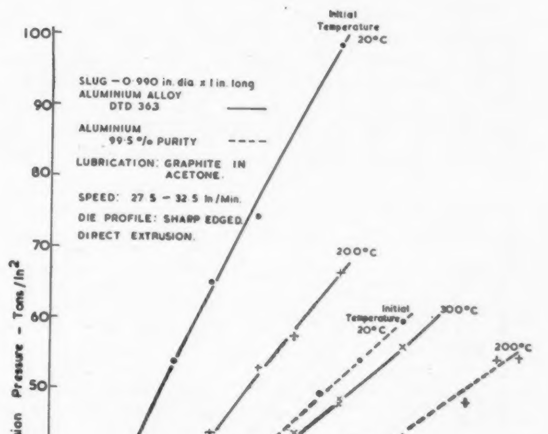


Fig. 3. Pressure required to extrude 99.5% purity aluminium and aluminium alloy DTD363 at different reductions and temperatures.

TABLE 2

Values of the constants a and b in the relationship between maximum extrusion pressure P and extrusion ratio $\frac{A_0}{A}$ for aluminium 99.5% purity and aluminium alloy DTD363 at different billet temperatures.

$$p = a \ln \frac{Ao}{A} + b$$

Initial slug temperature (°C)	*Aluminium 99.5% purity*			*Aluminium Alloy DTD363*		
	Valid range of extrusion ratio $\frac{Ao}{A}$	*Constants tons/in²*		*Valid range of extrusion ratio* $\frac{Ao}{A}$	*Constants tons/in²*	
		a	*b*		*a*	*b*
20	4 to 50	12.6	13	4 to 25	24.5	20
200	4 to 200	9.8	5.5	4 to 25	16.5	14
300	4 to 150	6.7	3.5	4 to 50	11.0	13
400	4 to 100	4.8	0.5	4 to 15	10.8	4

Ram speed range: 27.5 - 32.5 in./min
Lubricant: Graphite in acetone

DTD363 from billets at initial temperatures of 20°C. 200°C, 300°C and 400°C are shown in Fig. 3. At an extrusion ratio of 10, increasing the initial billet temperature from 20°C to 400°C resulted in a 70% drop in pressure required to extrude aluminium 99.5% purity and a 60% drop in that required to extrude the alloy DTD363. The excess pressure required to extrude rod in alloy DTD363 over that for the 99.5% aluminium increased with initial billet temperature from 80% at room temperature (20°C) to approximately 140% at an initial billet temperature of 400°C.

For extrusion ratios greater than 4, the extrusion pressure p is related to the extrusion ratio $\frac{A_0}{A}$ in the form:

$$p = a \ln \frac{A_0}{A} + b \text{ tons/in}^2$$

where a and b are constants. The values of these constants for the tests conducted at different billet temperatures are given in Table 2 for both materials

At a given reduction, the maximum extrusion pressure p was linearly related to the initial slug temperature, T, as shown in Fig. 4, by:

$$p = A - \gamma T \text{ tons/in}^2$$

where A and γ are constants. For rod extruded from billets at initial temperatures ranging from 20°C to 400°C, these constants were:

Material	Extrusion ratio	A tons/in²	γ tons/in²	$\frac{A}{\gamma}$
Aluminium 99.5 per cent purity	100	77	0.136	566
	30	58	0.103	563
	10	42.5	0.077	550
Aluminium alloy DTD 363	10	80	0.134	596
	4	55.5	0.090	612

It will be noted that the pressure-temperature characteristics obtained for the extrusion of aluminium 99.5% purity and aluminium alloy DTD363 converged and intercepted the abscissa at temperatures

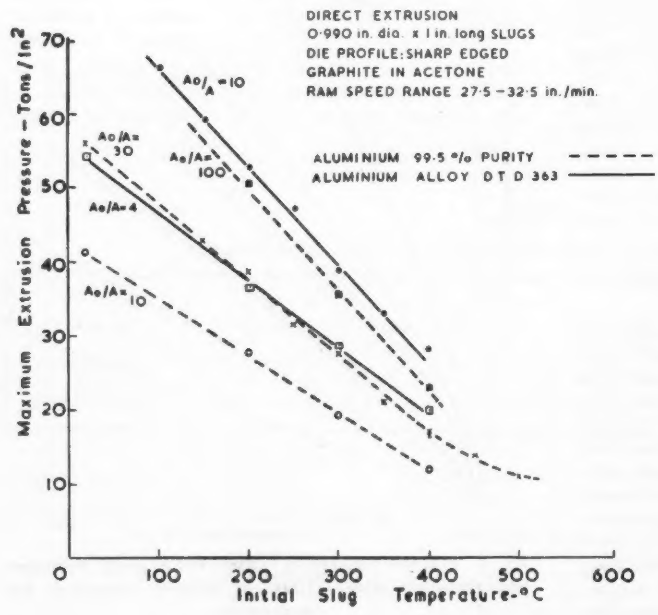


Fig. 4. Pressure required to extrude 99.5% purity aluminium and aluminium alloy DTD363 at different temperatures.

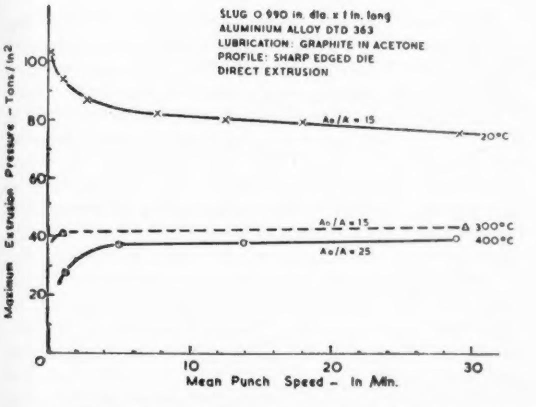


Fig. 5. Effect of speed on maximum extrusion pressure to extrude aluminium alloy DTD363 through sharp entry dies, using graphite in acetone as lubricant.

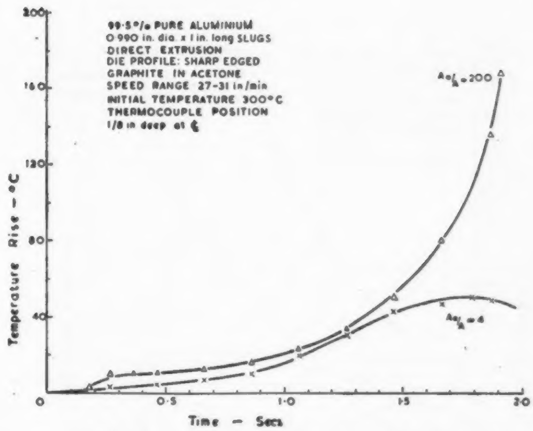


Fig. 6. Temperature rises in pure aluminium (99.5% purity) extruded at different reductions from 300°C

of approximately 565°C and 605°C respectively; and that the ratio $\frac{A}{\gamma}$ was approximately constan for both materials. From the limited data available, it was not possible to assess whether these observations had any physical significance.

(*b*) *effect of speed on the maximum extrusion pressure*

The effect of ram speed on the maximum pressures required to extrude rod from billets at initial temperatures of 300°C and 400°C was examined only for the alloy DTD363. The results obtained are shown in Fig. 5, and are compared with the effect of speed on the maximum pressure required to extrude rod at room temperature.

It will be noted that for tests conducted at initial temperatures of 20°C, 300°C and 400°C, the effect of ram speed appears to be significant for values less than approximately 8 in./min. Thus at billet temperatures of 300°C and 400°C the maximum pressure increased and at billet temperature of 20°C the maximum pressure decreased as the ram speed increased to 8 in./min. As the ram speed increased beyond this value to 30 in./min. the maximum pressure was relatively unaffected.

(*c*) *temperature rise during extrusion*

The temperature rise over a range of extrusion ratios, ram speeds and initial billet temperatures during the extrusion of rod was measured by means of a thermocouple located on the centre line of the billet just below the punch face.

Typical results showing the effect of increasing extrusion ratio on the temperature rise at a point $\frac{1}{8}$ in. below the punch face during the extrusion of aluminium 99.5% at a ram speed of approximately 30 in./min. from billets initially at 300°C are given in Fig. 6. It will be noted that due to the greater work of deformation, the temperature rise increased significantly with increasing extrusion ratio, the increase being approximately 170°C at an extrusion ratio of 200; that is, the billet temperature was approximately 470°C at this stage of the extrusion.

In the extrusion of alloy DTD363 at an extrusion ratio of 25, the temperature rise was measured by a thermocouple located within the billet at a depth of $\frac{1}{32}$ in. below the punch face. Typical results showing the increases observed in billets initially at 200°C, and 400°C are given in Fig. 7. The points of inflexion at about 1.6 sec. were thought to be due to the displacement of the thermocouple resulting from the change in metal flow at the onset of piping. It will be noted that the increase in temperature ranged from 120°C to 130°C dependent on the initial billet temperature. Subsequent tests confirmed that hot shortness or

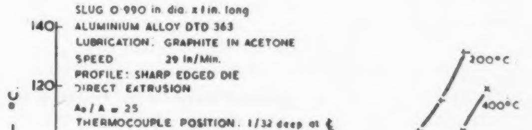


Fig. 7. Temperature rises in aluminium alloy DTD363 extruded from different initial temperatures.

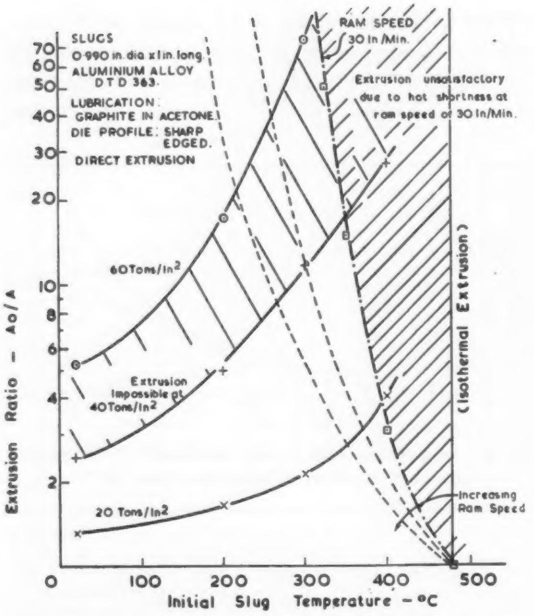


Fig. 8. Limiting curves for the extrusion of aluminium alloy DTD363.

circumferential cracking of the product occurred when the temperature of the metal reached approximately 480°C during extrusion.

In industry, the alloy is extruded at slow ram speeds and at an initial temperature of about 400°C. The principal reason for slow ram speeds at these higher extrusion temperatures is to prevent the onset of hot-shortness with failure of the extruded product. Thus, hot-shortness imposes a limit on ram speed, extrusion ratio and initial temperature of the metal.

Hirst and Ursell[5] have considered some limiting conditions on the extrusion process and have expressed them in the form of a family of curves on a graph of extrusion ratio against initial slug temperature. Some of the experimental results of this report are plotted in Fig. 8 to present in a similar manner some limiting conditions established for the extrusion of alloy. The curves to the left of Fig. 8, e.g. one marked 40 tons/sq. in., represent the combination of initial slug temperature and extrusion ratio that would require this maximum extrusion pressure (e.g 40 tons/sq. in.) to extrude rod under the conditions indicated on the diagram. The curves of 20, 40 and 60 tons/sq. in. represent the maximum values of extrusion pressure that could be obtained from given press capacities and slug dimensions. The curve for a ram speed of 30 in./min. represents the upper limits of the combinations of extrusion ratio and inititial slug temperature within which a rod can be extruded without the onset of hot-shortness. Thus, the practical working range for the extrusion of the alloy will be below the appropriate speed and pressure lines. Since the extrusion pressure varies with ram speed then each curve for ram speed must be accompanied by its appropriate pressure curves.

(*d*) *examination of the extruded products*

The diameters of the extruded rods were measured at various intervals along their lengths. In general, the diameter decreased progressively from the leading end to the discard end of the rod. This variation in diameter from end to end increased markedly with ram speed.

Typical measurements made on the rods extruded from alloy DTD363 are given in Table 3. The variation in diameter over a 12 in. length of rod increased from 0.0010 in. at a ram speed of 1.1 in./min. to 0.0045 in. at 18.0 in./min. During moderate- and high-speed extrusions, large increases of temperature occur and the product may have a considerable temperature difference from end to end. The temperature

TABLE 3

Effect of Speed on the Variation in Diameter of Extruded Rod in Aluminium Alloy DTD363

Ram Speed (in./min.)	*Diameter of the Extruded Rod (in.)*					*Change in Diameter over 12 in. (in.)*
	At the Front	*Distance from the Front*				
		3 in.	*6 in.*	*9 in.*	*12 in.*	
1.1	0.2580	0.2577	0.2573	0.2570	0.2570	0.0010
2.8	0.2580	0.2574	0.2569	0.2564	0.2562	0.0012
7.7	0.2580	0.2570	0.2566	0.2562	0.2557	0.0023
12.5	0.2578	0.2555	0.2548	0.2547	0.2539	0.0039
18.0	0.2570	0.2545	0.2533	0.2528	0.2525	0.0045

Lubricant: Sulphonated Tallow
Initial slug temperature: 20°C
Diameter of die aperture: 0.2580 in.

TABLE 4

Effect of Initial Slug Temperature on the Variation in Diameter of Extruded Rod in Aluminium Alloy DTD363

Initial Slug Temperature (°C)	*Diameter of the Extruded Rod (in.)*					*Change in Diameter over 8 in. (in.)*
	At the Front	*Distance from the Front*				
		2 in.	*4 in.*	*6 in.*	*8 in.*	
20	0.3112	0.3109	0.3106	0.3105	0.3100	0.0012
100	0.3114	0.3104	0.3102	0.3102	0.3079	0.0017
200	0.3110	0.3100	0.3100	0.3100	0.3098	0.0012
300	0.3107	0.3098	0.3094	0.3095	0.3093	0.0014

Lubricant: Graphite in acetone
Ram speed: 29 in./min.
Diameter of die aperture at 20°C: 0.3120 in.
Diameter of die aperture at 300°C: 0.3130 in.

difference necessary to produce a change of 0.0045 in. was estimated to be about 800°C. As temperature changes of this order did not occur, the contraction in diameter must be in part due to inertia effects resulting from the higher speed of the extruding rod and is analogous to the effect of speed on the flow of a fluid through an orifice.

The effect of different initial slug temperatures on the change in rod diameter over an 8 in. length is shown in Table 4. These changes were small compared with those due to the speed effect and no definite trend was evident.

Hardness measurements were made along the length of selected rods extruded at ratios of 6 and 10 respectively from billets of aluminium 99.5% purity and alloy DTD363 having initial hardnesses of 21 HV5 and 60 HV5 respectively. In extrusion at room temperature, the hardness of aluminium 99.5% purity increased to 55 HV5, whilst that of the alloy increased to approximately 87 HV5. The distribution of hardness was uniform along the length of the aluminium product, but varied from 99 HV5 at the leading end to 74 HV5 at the discard end in the alloy rod. Since the alloy is heat treated after extrusion, this variation in hardness in the extruded condition is unimportant.

The distribution of hardness along the length of rods extruded from billets of aluminium 99.5% purity remained uniform as the extrusion ratio increased from 1.23 to 15, indicating that even the low reductions are enough to take the material into the fully hardened state. At an extrusion ratio of 15, an increase in ram speed from 5 in./min. to 30 in./min. resulted in a decrease in the hardness of the rod from 56 to 51 HV5, but the distributions along the length were reasonably uniform.

cold extrusion of non-ferrous metals

Whilst billets are normally extruded into semi-finished products at elevated temperatures this is clearly unnecessary in the case of many metals, and the operation could be carried out equally successfully at room temperature. Although a larger press capacity is required to produce a given reduction, the cold extrusion process offers many advantages. The heating of billets and press tooling prior to extrusion is eliminated and whilst the latter is operating at an appreciably higher stress, the deleterious effects of temperature have been removed. It is possible to lubricate the billet much more effectively and this together with the absence of a temperature gradient which normally exists at the billet container interface results in a vastly different flow characteristic, and a product of much improved surface finish and appearance. Since the material is cold worked during extrusion its mechanical properties are enhanced and in many instances this is a desirable feature. In the case of the high strength alloys which are heat treated after extrusion this is of no significance, but freedom from the onset of hot shortness over a wide range of operating speeds is assured. In the cases examined to date there is evidence that the process gives a desirable fine-grain structure.

Quadt[6] has since reported extensive development work on the cold extrusion of the heat-treatable aluminium alloys, initially those containing copper, magnesium and silicon and latterly the more complex types containing zinc, magnesium and copper. He states that this class of alloys appears to offer less difficulty during extrusion than the non-heat treatable alloys. He draws attention to the fine relatively equi-axed recrystallised grain structure and to the possibility of being able to guarantee the same properties in the transverse direction as in the longitudinal direction, even in the direction-sensitive alloys of the aluminium-zinc-magnesium-copper series.

A study[1] has been made of the extrusion of some non-ferrous metals at room temperature to determine the effect of extrusion method, billet dimensions, ram speed, extrusion ratio, tool geometry and lubrication on the pressure required to extrude simple shapes and on the temperature distribution set up in the billet during extrusion. The tests were conducted with the

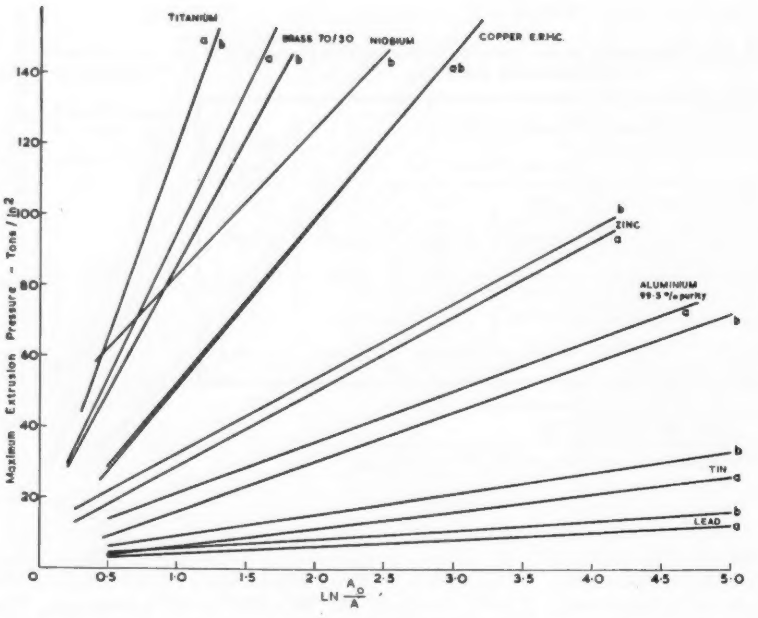


Fig. 9. Maximum pressure required to extrude rods over a range of reductions in different metals at (a) relatively slow ram speeds ranging from 0.4 to 5.5 in./min. and at (b) fast speeds ranging from 1.3 to 15.7 in./sec.

sub-press mounted in a hydraulic press capable of giving ram speeds up to 90 in./min. Cylindrical specimens of 0.995 in. diameter and 1 in. long in chemical lead, aluminium 99.5% purity, copper E.R.H.C. and 70/30 brass were machined from bar stock and annealed in vacuum for 3 hours at 150°C and 1 hour at 350°C, 500°C and 600°C, respectively, prior to extrusion.

(*a*) *effect of reduction on the extrusion pressure*

Rods, tubes and cans were extruded in aluminium, copper and brass at different extrusion ratios at a ram speed of 5.5 in./min. using sulphonated tallow as a lubricant.

Typical results for the extrusion of rod at extrusion ratios ranging from 1.23 to 178, 7.1 and 4.0 for aluminium, copper and brass respectively are shown in Fig. 9. It will be noted that the extrusion pressure, p, was related to the extrusion ratio $\frac{A_0}{A}$ as before, in the form:

99.5% Aluminium $\quad p = 14.5 \ln \frac{A_0}{A} + 6.9$ tons/in²

E.R.H.C. Copper $\quad p = 46.9 \ln \frac{A_0}{A} + 5.2$ tons/in²

70/30 Brass $\quad p = 89.4 \ln \frac{A_0}{A} + 0.7$ tons/in²

Similar relationships were obtained for the extrusion of aluminium and copper tubes, and for thick-walled aluminium and copper cans, the actual values of the constants a and b being the same within ±5% for each material.

Satisfactory products were obtained in all cases except during the extrusion of rod in aluminium at an extrusion ratio of 178, when the product emerged from the die in short bursts of 3 to 4 in. length and was accompanied by a marked fluctuation in extrusion pressure.

In an investigation of metal flow in cold extrusion, Chang[7] extruded rods, tubes and cans in pure lead, aluminium 99.5% purity, tin and zinc at different extrusion ratios at constant ram speeds of 0.4 in./min. in a testing machine and of 1.3 in./sec. in a hydraulic press. Typical results for the inverted extrusion of all three products are also given in Fig. 9. At both ram speeds the extrusion pressure, p, was linearly related to the logarithm of the extrusion ratio, typical relationships for extrusion at a ram speed of 1.3 in./sec. being:

Tin $\quad p = 6 \ln \frac{A_0}{A} + 3$ tons/in²

Zinc $\quad p = 21.1 \ln \frac{A_0}{A} + 11.5$ tons/in²

Lead $\quad p = 2.7 \ln \frac{A_0}{A} + 2.5$ tons/in²

It should be noted, however, that the length of the tin and lead billets was 0.75 in. whereas all other billets were of 1 in. length. The maximum pressure required to extrude the smaller billet would be less than that required for the billet 1 in. long.

Johnson[8] proposed that the extrusion pressure, p, be related to the extrusion ratio $\frac{A_0}{A}$ in the form:

$$\frac{p}{Y_m} = a_1 \ln \frac{A_0}{A} + b_1 = \varepsilon_m$$

where a_1 and b_1 were constants and Y_m the uniaxial yield stress of the material. The right-hand side of this relation could be regarded as the mean strain ε_m imparted to the extruded product, and estimated from measurements of p and Y_m during the extrusion of a

non-work hardening material such as lead. The results of such measurements gave the relationship:

$$p = Y_m \left(1.5 \ln \frac{A_o}{A} + 0.8\right).$$

Johnson suggested that the overall strain set up in the cold extrusion of a strain hardening material closely approximated to that undergone by a non-hardening material under similar conditions. The differential hardening was accounted for by the average value of the true stress Y_m over a range of strains from 0 to $(0.8 + 1.5 \ln \frac{A_o}{A})$ and could be obtained from the stress-strain characteristic of the material determined under comparable conditions of strain rate. For the extrusion of pure lead, tellurium lead, pure tin and super purity aluminium at the slow ram speed of 0.1 in./min. Johnson found good agreement between the values of extrusion pressure and those calculated using the above relationship and the appropriate stress-strain data.

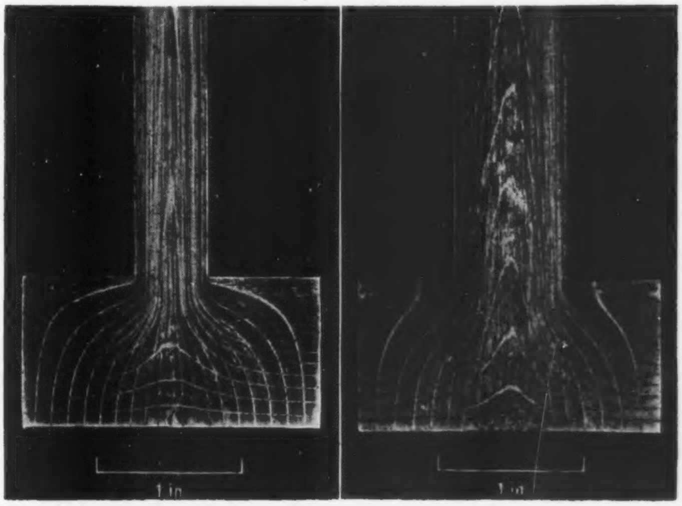
There are considerable difficulties, however, in deriving accurate stress-strain data for such materials in compression. Strains in excess of 2 are difficult to achieve and Johnson used extrapolated values of stress for strains between 3 and 5 which are common in extrusion. Further, frictional effects at the specimen ends become significant if its height is reduced below its diameter, and it is usual to machine the diameter of the compressed specimen at intervals to maintain equality with height. This gives rise to serious problems as the ram speed increases. At these higher speeds temperature effects due to the work of deformation also become important, and its influence in the compression test may differ significantly from that in extrusion.

In the current tests reliable stress-strain data for the compression of aluminium, copper and brass at the appropriate strain rate were available only for strains up to approximately 1.8. Over the very limited range of extrusion ratios 1.5 to 2.8 there was reasonable agreement between the values of the extrusion pressure obtained experimentally and those calculated from the above relationship. No stress-strain data were available for the materials used by Chang in his investigation.

Pearson classifies three modes of flow in direct extrusion according to the material and the operating conditions. A study of the numerous deformation patterns available for the direct and inverted extrusion of rod in lead, aluminium, copper, brass 70/30 and of the few available for titanium, shows that only the first mode described as Class A is operative at room temperature. A typical example of this deformation made in aluminium at extrusion ratios of 7 and 16 is shown in Fig. 10. The slug undergoes no appreciable deformation until it reaches the zone immediately in front of the die where shearing occurs within the billet without the formation of a dead metal zone.

(*b*) *the effect of ram speed*

A detailed study was made of the effect of ram speed on the extrusion of rod in aluminium 99.5% purity at an extrusion ratio of 16. Typical extrusion pressure-punch displacement characteristics obtained at constant ram speeds of 0.4 in., 9.5 in., 22 in. and 35 in./min. are shown in Fig. 11. The characteristics of the extrusions conducted at ram speeds in excess of 9.5 in./min. appear to be identical and differ from that obtained at a ram speed of 0.4 in./min. It was found that the maximum extrusion pressure decreased sharply as the ram speed increased from 0.4 in. to 1.0 in./min. and then more gradually to a minimum value at a ram speed of 5.5 in./min. This decrease in maximum extrusion pressure amounted to 15% at 5.5 in./min. and thereafter increased gradually by 5% as the ram speed increased from 5.5 to 90 in./min.



$\frac{A_o}{A} = 16$ $\frac{A_o}{A} = 7$

Fig. 10. Mode of deformation in the cold extrusion of aluminium.

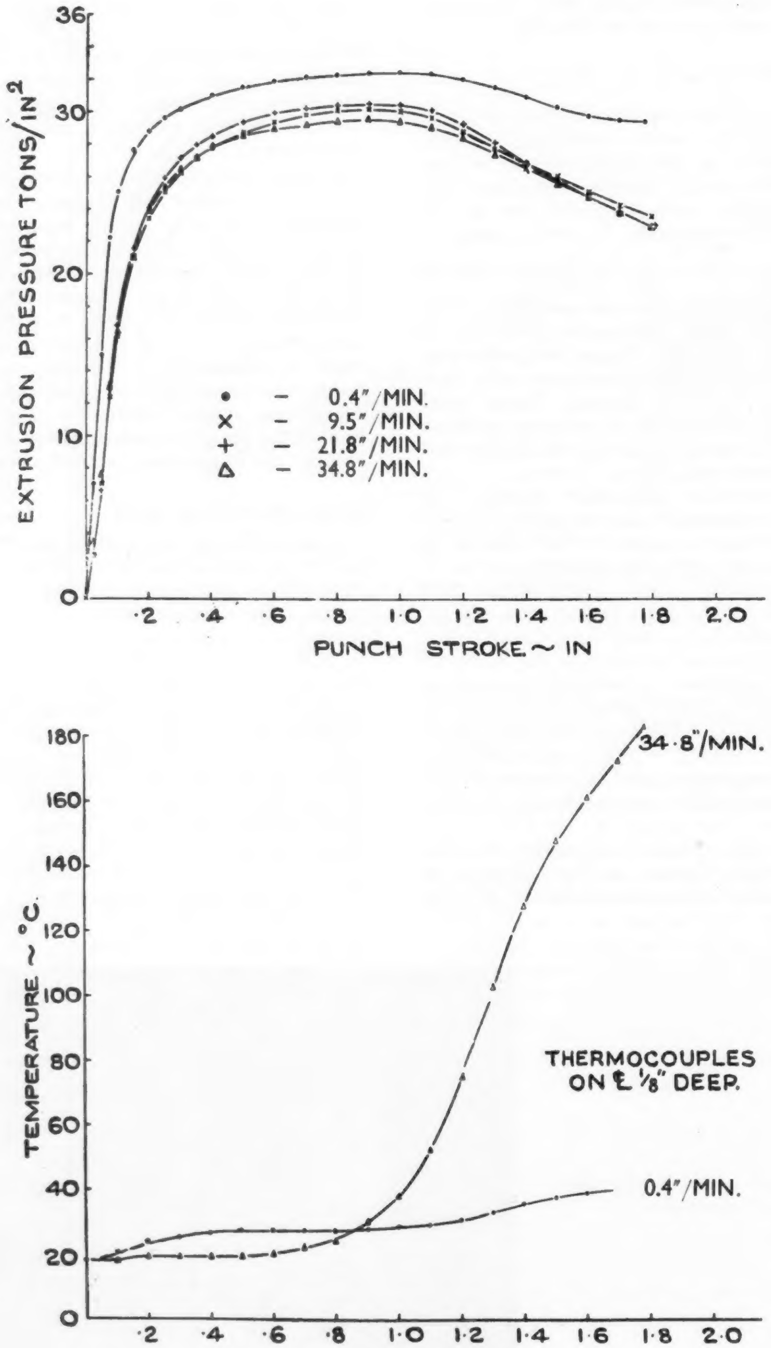


Fig. 11. Effect of speed on the pressure and temperature displacement characteristics for the inverted extrusion of aluminium rod at a reduction of 86% using sulphonated tallow as lubricant.

The influence of ram speed was dependent on the extrusion ratio, thus the decrease in extrusion pressure as the ram speed increased from 1.0 to 5.5 in./min. was approximately 3% at an extrusion ratio of 2.8 and 10% at an extrusion ratio of 178.

Less detailed studies of the extrusion of rods and tubes at different extrusion ratios from billets of copper and 70/30 brass lubricated with sulphonated tallow were made at selected ram speeds within the range 1 to 25 in./min. As before, the maximum extrusion pressure decreased as the ram speed was increased from 1.0 in. to approximately 25 in./min. At an extrusion ratio of 2.8, this decrease in pressure required to extrude copper and brass was approximately 5% and 10% respectively.

It is interesting to note that Chang[9] found an increase of 25% in the pressure required to extrude lead as the ram speed was increased from 0.05 in. to 8.0 in./min. He reports that over this range of ram speed the effect on the pressure required to extrude aluminium rods was not significant but that there was a definite downward trend in the pressure at the higher speeds with large extrusion ratios.

In a further series of tests[7] he found that the maximum pressure required for the backward extrusion of rod in tin and zinc increased by approximately 30% and 5% as the ram speed increased from 0.4 in./min. to 1.3 in./sec. at an extrusion ratio of 55.

These apparently different effects of ram speed on the pressures required to extrude simple shapes are primarily due to the opposing influences of work hardening and thermal softening which occur in the material during deformation. Thus, as the ram speed is increased, the resistance of the material to deformation is increased, the extent of the increase being dependent on the material and on the rate of strain. This will result in an increase in extrusion pressure. The heat generated by the work of deformation also increases with increasing yield stress and depending on the thermal characteristics of the material and the geometry of the extrusion, this may increase the temperature of the billet. If this is sufficient to produce significant thermal softening it will lower the extrusion pressure. Thus the net effect of increasing ram speed will depend on which of these influences predominate.

In an investigation of the yield stress of pure lead in compression using a cam plastometer, Loizou and Sims[10] found that the stress required to produce a 50% reduction in the height of cylindrical specimens was increased by approximately 14% as the strain rate was increased from 1 to 20 sec.$^{-1}$. The rise in temperature of the specimen during compression increased from 17°C to only 18.6°C as the strain rate was increased from 0.8 to 11.8 in./sec. Under these conditions the effect of increasing strain rate on the yield stress is more significant than the effect of thermal softening.

In similar compression tests Alder and Phillips[11] found that the stress required to produce a 50% reduction in height of cylindrical specimens of commercially pure aluminium increased by 10% as the rate of strain was increased from static tests to 1.3 sec.$^{-1}$. The stress required to produce a similar reduction in specimens of phosphorus deoxided copper increased by 5% as the rate of strain was increased from that of static

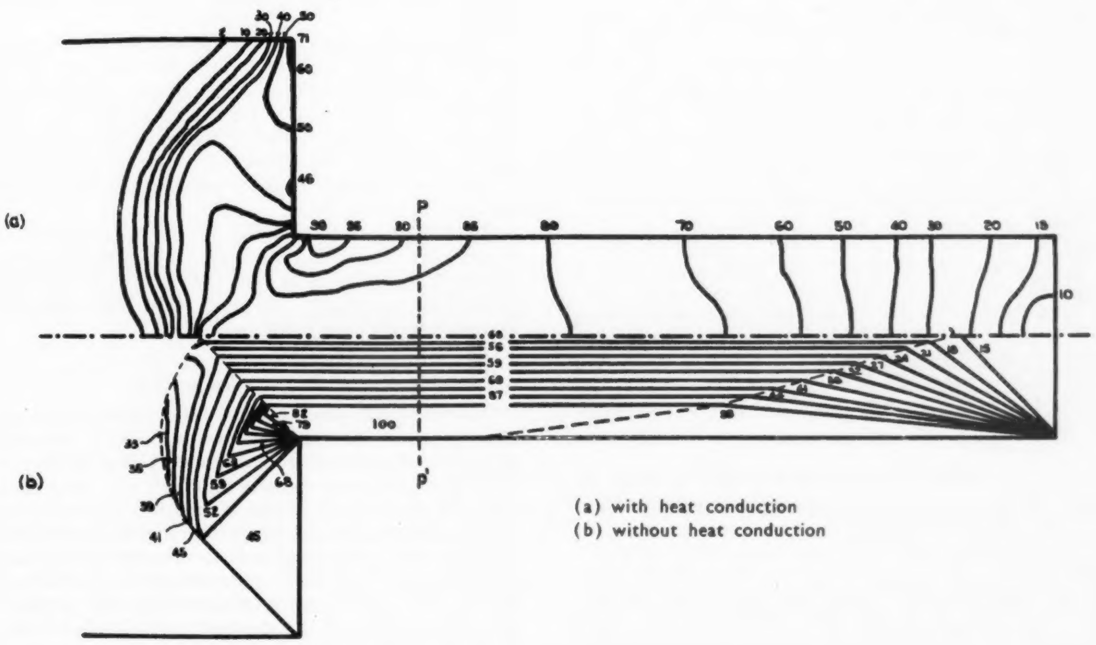


Fig. 12. Isothermals in copper billet 1.2 sec. after commencement of plane strain extrusion through a smooth square die with 66.7% reduction at a ram speed of 5 cm./sec.

tests to 4.4 sec.$^{-1}$ and only 2% as the strain rate increased from 4.4 sec.$^{-1}$ to 23 sec.$^{-1}$.

When considered in relation to these effects of strain rate and temperature rise the influence of ram speed appears in a more rational light.

(*c*) *temperature rise during extrusion*

Even in the extrusion of metals at room temperature, the increase in temperature of the slug due to plastic working has important implications. If the increase is sufficiently large then not only would it alter the yield strength of the material and consequently the pressure required throughout the extrusion stroke, but also it would have a significant effect on the properties of the extruded product. In fact in both hot and cold extrusion the significant temperature is that at which the product emerges from the die.

A method of calculating the increase in temperature of the billet and product during extrusion has been developed by Bishop[12] and extended by Green[13] to include the axi-symmetric case. Both have considered the general problem of time dependent heat flow in a moving medium with heat generation in the medium with and without conduction. The former has determined the isothermals for plane strain extrusion of copper through a sharp entry die with a reduction of 66.7% at a ram speed of 5 cm./sec. The isothermals set up in the material 1.2 secs after the commencement of the extrusion with and without heat conduction are shown in Fig. 12. Green has prepared a programme for a DEUCE computer, from which it will be possible to ascertain the effect of increasing reduction and ram speed.

An extensive series of measurements show that the temperature rise at a point on the axis of symmetry immediately below the punch face appears to be independent of the method of extrusion, of the billet length to diameter ratio, of the lubricant and of the die geometry. These factors, however, have a considerable influence on the temperature distribution at points within the billet adjacent to the container walls, and die face and also on the shape of the temperature-punch displacement characteristic.

The factors which profoundly influence the rise in temperature of the billet due to work of deformation are reduction and ram speed. The effect of reduction on the temperature rise with slugs of 0.995 in. diameter and 1 in. length during the extrusion of rod in copper and brass 70/30 under lubricated conditions at a ram speed of 5.5 in./min. is clearly seen from some typical results given in Fig. 13. It will be noted that the temperature rise within the billet increases as the reduction is increased. For comparable reductions the temperature increase is greater in brass than in copper because of the greater work of deformation required for the extrusion of brass, coupled with a thermal conductivity which is significantly lower than that of copper.

The effect of ram speed on the increase in temperature measured at a point $\frac{1}{8}$ in. within and along the axis of the billet of aluminium 99.5% purity during extrusion is also shown in Fig. 11. A marked increase from 30° to 180°C in the temperature rise recorded within the billet was observed as the constant ram speed was increased from a value of 0.4 in. to 34.8 in./min.

This appreciable increase in temperature rise is presumably due to the correspondingly shorter period available for loss of heat from the billet by conduction along the specimen, through the billet-chamber interface and through the punch.

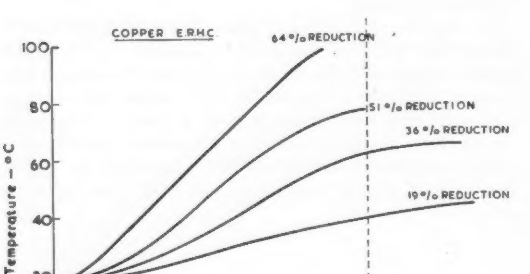


Fig. 13. Effect of reduction on temperature rise inside slug during direct extrusion of rod.

(*d*) *examination of the extruded product*

The effect of ram speed is also apparent in the dimensions of the extruded product. In the inverted extrusion of rod from 2 in. diameter billets of aluminium 99.5% purity products of length 7 ft. and 11 ft. were obtained from billets of length 2 in. and 3 in. The diameter of product at different positions from its leading end was particularly dependent on the ram speed as seen from Table 5. Although temperatures of 260°C and 300°C were attained by the products towards the end of the extrusion of billets of length 2 in. and 3 in. respectively, this could not account entirely for the dimensional changes observed. It will be noted however that after the first 12 in. of material

TABLE 5

Effect of ram speed on the dimensions of aluminium rod backward extruded through a sharp-edged die of 0.283 in. diameter at an extrusion ratio of 50

Ram Speed in./min.	*Diameter (in.) of product at following distance from leading end*								
	0 in.	*1 in.*	*6 in.*	*12 in.*	*24 in.*	*48 in.*	*72 in.*	*84 in.*	*132 in.*
30	0.2814	0.2810	0.2801	0.2798	0.2795	0.2793	0.2792	0.2792	0.2785
20	0.2814	0.2807	0.2802	0.2800	0.2797	0.2796	0.2794	0.2792	
8	0.2814	0.2812	0.2805	0.2803	0.2802	0.2800	0.2798	0.2795	
1.6	0.2825	0.2815	0.2812	0.2810	0.2809	0.2807	0.2803	0.2799	

has been extruded the subsequent change in diameter is only 0.001 in. over a length of 6 ft. and 0.0015 in. over a length of 10 ft.

cold impact extrusion

Although the process of cold impact extrusion has been known for a considerable time, its application to other than soft metals is only of fairly recent origin, being now applied to larger and longer products in many materials including the more exotic types like molybdenum, zirconium, Zircaloy, uranium, niobium and titanium.[14] Hitherto, the manufacture of most engineering components involved extensive machining with consequent material wastage, commonly in the region of 50% and sometimes as high as 90%. In order to reduce production costs and material wastage, there has been a general trend to eliminate machining operations as far as possible. This fact, together with the other advantages of improved output, the quality and dimensional accuracy of the product and the ability to produce simply a wide range of shapes, has resulted in the rapidly growing importance of cold extrusion of both non-ferrous and ferrous materials. Both the dearth of information and the effects of many variables, particularly in the case of steel, have tended to delay the application of this process.

Except for very simple products, the technique consisted of a number of operations carried out in sequence or sometimes simultaneously and involved forward extrusion, backward extrusion, upsetting, piercing, coining, etc. Thus the tooling for the working and transfer of components might be quite complicated and costly, particularly for the cold extrusion of steel, and in such cases, the process can only be economical if large numbers of products are required on a mass-production basis.

The process is particularly suited to, and is mainly used for, the production of axially-symmetrical components. The solid components can be made with heads of all shapes or with stepped shanks of different diameters while the hollow ones can be completely open or closed at one point. Both the inner and outer surfaces of the hollow components can be produced with lands, flutes, splines, teeth, etc. Thus an almost endless variety of components is possible, such as cans, tubes, screws, bolts, studs, pins, rivets, in ferrous and non-ferrous materials, as well as steering ball joints, motor spindles, gudgeon pins, hydraulic cylinders, spark plug bodies, torsion tubes and car transmission gears in steels.

cold impact extrusion of non-ferrous metals

Since the impact extrusion of cans has been practised commercially for a considerable period, ideas on the design of tools, speeds of operation, blank preparation, etc., have crystallised from the accumulated experience. Much of this has since been supported by quantitative studies by Hanes[15], Galloway,[16] Gokyu and Suzuki,[17] Fukui Kudo and Seino,[18] and Watkins and McKenzie.[19]

In the work carried out at the National Engineering Laboratory, an investigation was made of the effect of selected factors on the extrusion of a number of non-ferrous metals.

Cylindrical specimens in aluminium 99.5% purity, copper and brass 70/30 were machined from extruded bar stock of $1\frac{1}{8}$ in. diameter. All specimens were annealed in vacuum prior to extrusion, aluminium for 1 hour at 350°C, copper for 1 hour at 500°C and brass for 1 hour at 600°C. Specimens of niobium were obtained as sintered slugs whilst the titanium specimens were machined from $1\frac{1}{2}$ in. diameter bar stock having an analysis of 0.012% C, 0.024% N, 0.096% Fe and remainder titanium. The titanium specimens were surface treated (Process EP 1004) by Pyrene Company Limited and subsequently lubricated with molybdenum disulphide in alcohol prior to extrusion.

The tests were carried out in a 150-ton crank press provided with facilities for adjusting the total stroke from 3 to 12 in. The speed of the crank could be varied from 10 to 60 rev./min. and at the latter speed, the punch head velocity on impact with a slug 1 in. long was 15.7 in./sec. and with a slug $\frac{1}{2}$ in. long, 11.6 in./sec.

(a) effect of reduction on extrusion pressure

This factor is of particular importance in assessing the press capacity required for a given operation.

Rods and tubes were forward extruded from 99.5% pure aluminium slugs of diameter 0.998 in. and heights of 1.0 in. and of 0.5 in. in the range of reductions of area from 19—96%. The crank press was operated at 60 rev./min. and the slugs lubricated with sulphonated tallow. It will be seen from Fig. 14 that the same pressures are required to extrude products of both

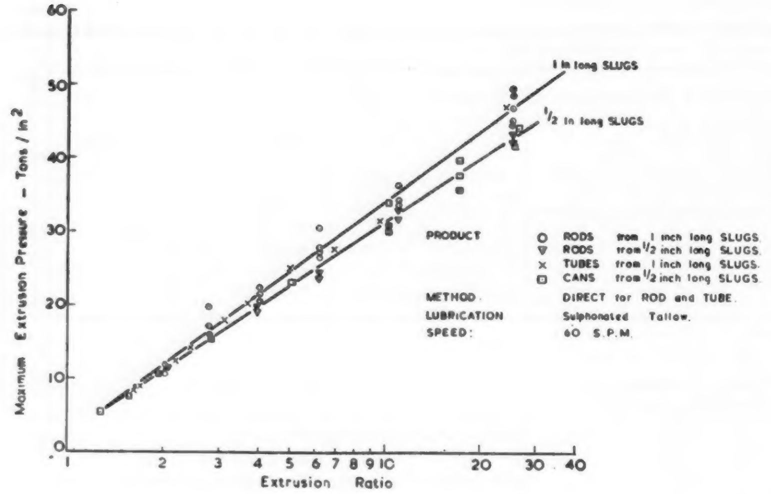


Fig. 14. Pressure required to extrude aluminium products from 1 in. (nominal) diameter slugs.

TABLE 6

Values of constants a and b for substitution in the relationship

$$p = a \ln \frac{A_0}{A} a + b$$

(1) as obtained in the impact extrusion of rod and tube under conditions specified

Metal	*Slug length in.*	*Punch speed in./sec.*	*Lubricant*	*a tons/sq. in.*	*b tons/sq. in.*
Aluminium super purity	0.5	1	Nil	12.0	2.5
	0.5	1	Light Machine Oil	12.2	0.5
	0.5	1	Tallow	12.0	0.8
	0.5	7	Tallow	12.2	2.0
	0.5	7	Light Machine Oil	12.6	2.7
Aluminium 99.5% purity	0.5	1	Nil	14.9	0
	0.5	1	Light Machine Oil	14.0	0
	0.5	1	Tallow	13.5	0.4
	0.5	7	Tallow	13.8	1.5
	1.0		Sulphonated Tallow	14.0	2.0
Aluminium 99% purity	0.5	1	Tallow	13.0	6.0
	0.5	7	Tallow	14.5	4.8
ERHC Copper	0.5	11.6	Sulphonated Tallow	37.4	3.5
	1.0	15.7	Sulphonated Tallow	47.7	3.5
70/30 Brass	0.5	11.6	Sulphonated Tallow	66.4	3.5
	1.0	15.7	Sulphonated Tallow	77.4	3.5
Niobium	0.5	11.6	Sulphonated Tallow	44.2	38.5
Titanium	1.0	15.7	Sulphonated Tallow	107.2	11.5

(2) as obtained in the impact extrusion of can under conditions specified

Aluminium super purity	0.05	61 rev./min.	Tallow	15.4	—15.0
	0.10		Tallow	13.2	— 4.0
	0.20		Tallow	12.2	0
	0.05	8.3 rev./min.	Tallow	18.0	—25.0
	0.10		Tallow	15.0	—10.0
	0.20		Tallow	13.2	— 4.0

types and that these are linearly related to the logarithm of the extrusion ratio as before, the values of the constants a and b being given in Table 6.

In order to allow a punch of reasonable length/diameter ratio to be used in the extrusion of cans the length of slug was restricted to $\frac{1}{2}$ in., thus limiting the height of can produced. It will be noted from Fig. 14 that the pressures required to extrude cans of different wall thicknesses are the same as those required to extrude rod of the same extrusion ratio and that these pressures are also linearly related to the logarithm of the extrusion ratio the constants being given in Table 6. Further, a decrease in slug length from 1 in. to 0.5 in. has significantly reduced the maximum pressure required to extrude a given product. This difference is probably due to the greater slug container friction with the longer slug. Thus for a given slug length a single expression would generally suffice to relate extrusion pressure and reduction for rod, tube and can in a given metal.

The effect of reduction on the maximum pressure required to extrude rod from copper and brass slugs of length 0.998 in., using sulphonated tallow as lubricant, is given in Fig. 9, as well as preliminary results on the extrusion of rod from sintered niobium slugs of length $\frac{1}{2}$ in. and from phosphate-coated titanium slugs of length 1 in., using molybdenum disulphide in alcohol as lubricant. The crank press was again operated at 60 rev./min. throughout all tests.

Whilst the maximum pressures required to extrude copper, brass and titanium at different reductions follow the same trend as those for aluminium, those required to extrude niobium appeared to be abnormally large at the smaller reductions. The constants a and b in the linear relation between the maximum pressure p and the extrusion ratios are given in Table 6.

Typical extrusion pressure/punch stroke characteristics for the extrusion of copper, brass and titanium at a reduction of 75% and a ram speed of 15.7 in./sec. are shown in Fig. 15. The characteristics for copper and brass are normal, but those for titanium differ appreciably in the very rapid rise to maximum pressure in the initial stages of the extrusion, followed by an equally rapid and pronounced fall which was repeated before reaching a value which remained approximately constant for the remainder of the stroke. The temperature rise inside the titanium rod was considerably greater than that in the other metals at the same reduction. The dips which occurred in the pressure-stroke characteristic of titanium at 75% reduction corresponded to slight necking of the extruded product and to the production of internal fish-tail tears. The necked portion of the rod nearest the discard end also showed signs of surface discolouration due to excessive heating.

(*b*) *effect of ram speed*

In the slow speed extrusion described above, it was found that for aluminium, copper and brass there was a drop in maximum extrusion pressure of 10%, 5% and 10% respectively as the ram speed was increased from 1 in./min. to 25 in./min. However, in the case of aluminium the greatest change occurred in the speed range up to 5 in./min.; therefore, provided the ram speed is greater than this value, it has little effect on the maximum extrusion pressure of these metals.

In the case of extrusions carried out in the crank press, the ram speed of course changes from a maximum value at impact to zero at the bottom of the stroke. However, it was found that the maximum pressure required to extrude rod and can was not significantly altered as the crank speed was increased over the range 10 to 60 strokes/in., corresponding to impact speeds varying from 1.6 to 9.9 in./sec. respectively. Typical maximum extrusion pressure-stroke curves for the extrusion of aluminium cans at 94% reduction are given in Fig. 16 and show that the maximum extrusion pressure increased by only 4% as the impact punch speed was increased over the range 1.6 to 9.9 in./sec.

In an extensive study of the extrusion of cans from slugs of 0.53 in. diameter and 0.195 in. thick, Fukui, Kudo and Seino, found that the maximum pressures required to extrude aluminium, soft copper and 65/35 brass under static conditions, in a testing machine, were 5%, 10% and 15% higher respectively than

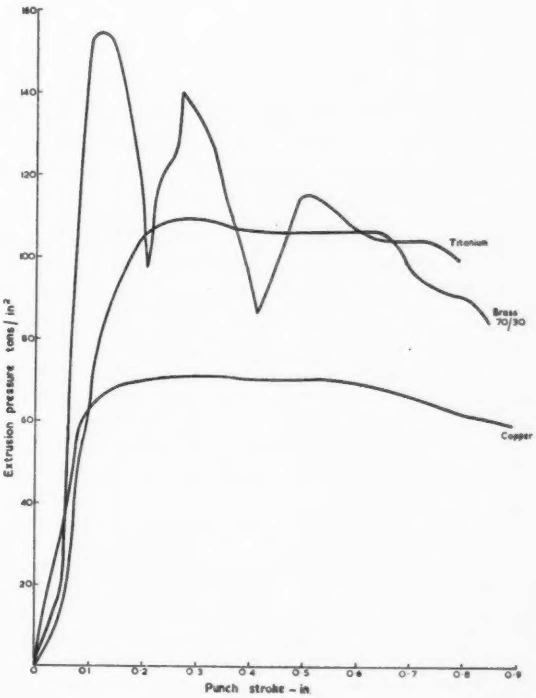


Fig. 15. Typical extrusion pressure — punch stroke characteristics for the extrusion of rod at 75% reduction in copper, brass 70/30 and titanium at a crank speed of 15.7 in./sec.

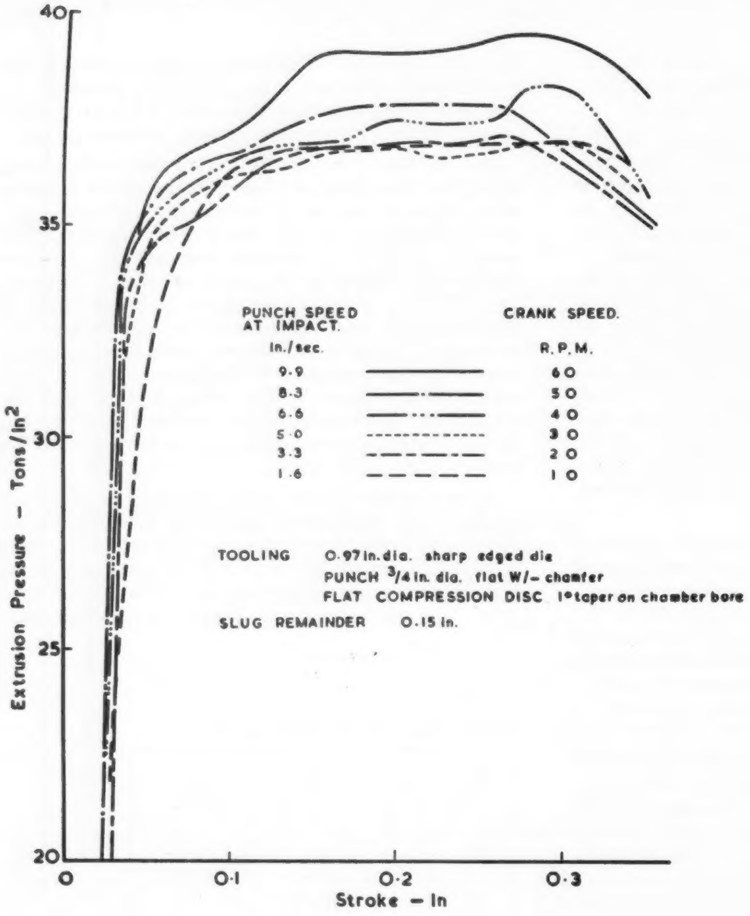


Fig. 16. Effect of speed on the pressure/stroke characteristics for the extrusion of cans at 94% reduction in aluminium 99.5% purity, using slugs of ½ in. length lubricated with sulphonated tallow.

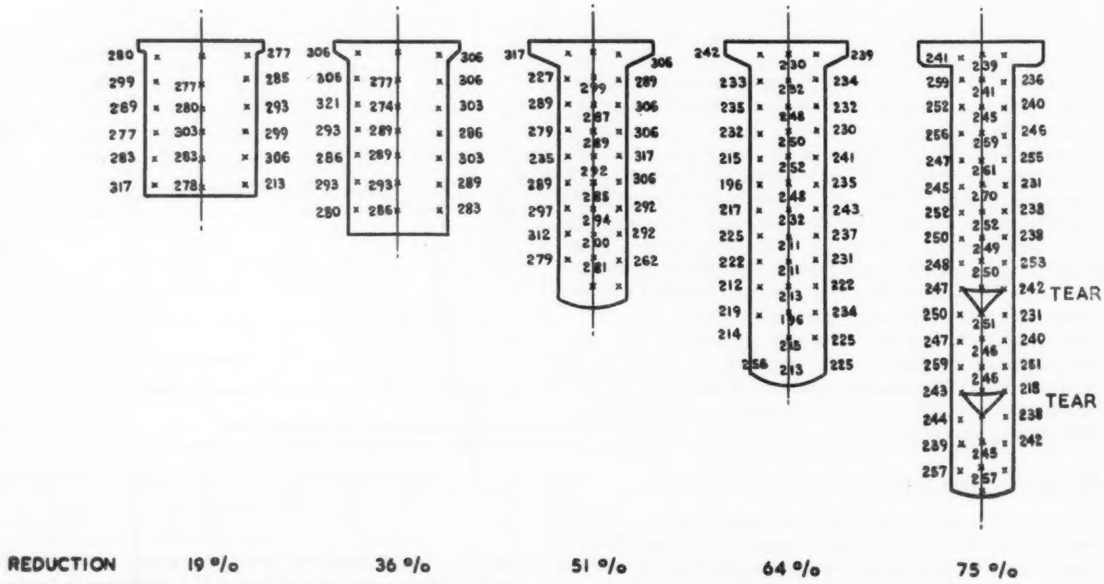


Fig. 17. Titanium extrusions — effect of reduction on hardness (HV30) of axially split specimens.

those required during an extrusion in a crank press. No indication was given whether the change took place at the extreme bottom end of the range as found in the present results. These results are in reasonable agreement with the present results, considering the differences in materials.

In tests in the forward extrusion of rod at reductions of 86% and 96% from slugs of aluminium of super and 99.5% purities, Los[20] confirmed the above finding and found that the extrusion pressure increased by only 3% as the impact speed of the punch was increased from 0.83 in./sec. to 8 in./sec. However, he also compared the pressure required to extrude rod in a testing machine at a constant ram speed of 2 in./min. with that obtained from extrusion in a crank press at an impact speed of 0.83 in./sec. and found that these were the same.

Thus, the general conclusion is that, provided the ram speed is greater than some low minimum value, viz., 5 in./min. in the case of aluminium, then it has no effect on extrusion pressure, even up to the high speed obtained in crank press operation. It would therefore appear that it does not greatly influence the mechanics of the process, but it is clearly of particular economic significance in that it influences the rate of production.

(c) *the effect of reduction on the properties of the extruded product*

It is expected that because of the non-uniformity of deformation in the extrusion process, variations in properties will exist throughout the product. In order to investigate this variation in the product used in this work, hardness traverses were made on polished sections taken through the axis of the product. A typical result is shown in Fig. 17 for titanium rods extruded with reductions ranging from 19 to 75%, from which it is apparent that the distribution of hardness is reasonably uniform across and along the length of the section. However, the hardness varied little as the reduction was increased from 19 to 51%, although when increased further to 75% lower values of hardness were obtained. It is clear from this that the material becomes fully work-hardened for reductions as small as 19%, and that increasing reduction has little effect. For reductions above 51%, however, it is apparent that sufficient heat is generated to induce some degree of thermal softening.

In the case of copper and brass rods, the outer periphery of the products was extensively hardened after small reductions and increased little with further reduction. This shows that even at small reductions there is extensive deformation on the outside surface produced by the die edge. The hardness values on the axis of the brass products increased progressively with larger reductions, the rod attaining uniform hardness across the section only after some 75% reduction. This again confirms that the outer edge is fully work-hardened at small reduction, but that the interior of the rod only achieves this state after a large reduction. The impression of the pyramid indenter was symmetrical on the axis, but markedly asymmetrical on the periphery, the degree of asymmetry decreasing with increasing reduction.

In the case of the backward extrusion of aluminium cans and the forward extrusion of niobium rods, a similar trend was observed, except that, as may be expected, higher hardnesses were obtained on the inner can wall where the material had been subjected to considerable deformation in passing over the punch head periphery, than on the outside surface which had been in contact with the chamber wall. For a given thickness, the hardness of the base appeared independent of reduction.

The importance of the temperatures generated in cold extrusion can be seen from the fact that under certain conditions, the properties can be adversely affected. Thus, copper rod extruded at a reduction of 96% at an impact punch speed of 16 in./sec. showed extensive re-crystallisation indicating that a temperature of about 500°C had been reached. The hardness along the axis of the rod decreased by 25% towards the discard end. This effect was also reported by Los in the case of the rod extrusion of super pure aluminium at 98% reduction and an impact speed of 7 in./sec. In this case the hardness decreased by a half at the discard end.

cold impact extrusion of ferrous metals

Steel was first successfully extruded in Germany in 1934 to provide an alternative process to deep drawing. Due to the fact that the stress system in extrusion is essentially compressive, whereas it is entirely tensile in deep drawing, it is possible for the same deformation to be obtained in one impact extrusion, as would require several deep-drawing operations with inter-stage annealing treatments.

The process has been under continuous development during the last 20 years in Germany, its range of application widened and its capabilities proved under commercial conditions. In the U.S.A., Government-sponsored research and development work at two firms immediately after the War has led to the know-how and industrial techniques which exist in that country today. Whilst developments abroad have been known for a number of years, it is only recently that the possibilities of the cold extrusion of steel as a production process are being generally explored in this country. The slowness in applying such processes may have been due to a lack of incentive, but more probably to a complete lack of expert knowledge of a new technology. Nowadays, there is no lack of incentive, and increasing pressure is being applied to many component manufacturers, particularly those associated with the automobile industry.

In order to provide authoritative data and an adequate background for the new technology, a study[21] has been made of the various factors governing the cold extrusion of steel. The effect of type of product, tool geometry, extrusion ratio, lubrication, ram speed and type of steel on the extrusion pressure, the flow of metal and the properties of the extruded product were investigated. The tests were conducted in the 150-ton crank press using a sub-press adequately tooled to accommodate the higher stresses experienced in the cold extrusion of steel.

Cylindrical specimens in the various steels of 0.998 in. diameter and 1 in. long were machined with

TABLE 7

Chemical composition, properties and heat-treatment of steels prior to extrusion.

Type of Steel	Steel specification	Chemical composition (remainder Fe)								Mechanical Properties			Heat treatment annealed 1 hour at temperature °C
		%C	%Mn	%Si	%Ni	%Cr	%S	%P	Others	YP tons/sq. in.	Tensile strength tons/sq. in.	Hardness HV30	
Armco Iron		0.03	0.048				0.028	0.014	—	9.6	20.0	80	900°
Low '15' carbon		0.15	0.61	0.1	0.06	—	0.050	0.026	—			—	900°
Free cutting	En 1A	0.10	1.08	0.03	0.06	—	0.275	0.047	—	16	25.6	—	900°
Cold forming	En 2A	0.15	0.63	0.04	0.22	—	0.04	0.023	—	{20 18.8	27.4 26.4	110— 120	890°
Cold forming	En 2C	0.24	0.6	0.02	0.08	0.02	0.032	0.026	—	17.6	29.6	125–135	890°
'20' Carbon	En 3	0.23	0.85	0.15	0.07	—	0.036	0.034	—	18.4	32.0	140	890°
'20' Carbon	En 3A	0.22	0.82	0.35	—	—	0.060	0.060	—	—	—	135	890°
'20' Carbon	En 3B	0.16	0.76	0.02	0.17	—	0.044	0.017	—	19.2	27.6	125	900/950°
C case hardening	En 32B	0.16	0.73	0.05	0.18	0.03	0.054	0.026	—	17.2	28.0	120	900/950°
Bright carbon steel	En 6	0.39	0.82	0.29	0.02	—	0.032	0.025	—	{22.2 24	39.2 39.2	180	860°
'40' Carbon	En 8	0.43	0.65	0.11	0.07	—	0.029	0.020	—	22.4	37.6	160	850°
'55' Carbon	En 9	0.62	1.16	0.17	0.08	—	0.028	0.021	—	28.8	56	230	840°
3% Ni—case hardening	En 33	0.11	0.41	0.23	2.96	0.14	0.027	0.008	—	24.4	32.0	170	600/650°
High carbon spring steel	En 44	1.03	0.70	0.17	0.14	0.05	0.041	0.034	0.05 Mo	26.5	43.5	215	820°
Carbon spring steel	En 42	0.78	0.63	0.18	0.07	0.04	0.038	0.032		34.8	52.6	200	850°
3% Cr.Mo nitriding	En 40B	0.32	0.49	0.3	0.2	3.02	0.017	0.020	0.42 Mo	56.0	85.0	180	900°
Ni-Cr-W Valve steel	En 54	0.41	0.71	1.40	14.65	14.35	0.01	0.024	2.53 W	27.2	56.0	255	950°
Austenitic Cr-Ni Rust, acid and heat resisting	En 58B	0.13	0.81	0.51	8.9	19.15	0.027	0.025	—	—	—	200	1050°

a longitudinal surface finish in the range 70 to 90 micro-inches C.L.A. and annealed in vacuum for 1 hour, prior to extrusion. The steels used were to B.S.En specifications and are listed with their annealing temperature, specific analysis and mechanical properties in Table 7.

Prior to the application of the lubricant, all slugs were given a coating of zinc phosphate as follows. The slugs were degreased in trichlorethylene, rinsed in hot water, pickled in a cold 7% hydrochloric acid solution, rinsed in hot water, cleaned in turpentine, phosphated, rinsed again with hot water, dried in an oven and lubricated. The zinc phosphate coating was applied by the Bonderite D.R. process, developed by the Pyrene Co., based on a 70 point solution of primary zinc phosphate and free phosphoric acid maintained at 85°C. Slugs in steels with chromium contents greater than 5% were degreased, immersed for five to ten minutes in a solution of Bonderite 'S.S.', held at 55°—60°C and then dried off in an oven at a temperature not exceeding 120°C.

After being coated, the slugs were immersed in the liquid lubricant; with the exception of Bonderlube A and Bonderlube 235, which were heated to 70°C, all lubricants were applied cold.

Since press loads and stresses on tooling are of particular importance, these were considered in detail in the extrusion of mild steel to B.S. specification En2A.

(a) effect of reduction

Rods, tubes and cans were extruded at extrusion ratios ranging from 1.11 (reduction 10%) to 6.25 (84%), 1.13 (12%) to 12 (92%) and 1.23 (18%) to 5.26 (81%) respectively. In some cases, the upper limit of the extrusion ratio, e.g., 12 in the case of the tube extrusion, induced very high stresses in the tooling (215 tons/sq. in.). Although the tooling successfully withstood such stresses, in the case of a few applications, under experimental conditions, it should be pointed out that it is not recommended that such large pressures should be used for continuous operation in production.

The maximum pressures required to extrude rod tube and can from slugs of En2A steel, lubricated with Bonderlube 235 at a crank speed of 10 strokes/min. are given in Fig. 18 for a range of extrusion ratios and for given punch and die profiles. The scatter in the values of pressure required to extrude rod and tube were found to be within ±5%, and within ±2% for cans.

Results indicate that at extrusion ratios of 1.5, 2.78 and 4.0, the maximum pressure required to extrude tubes is 6% lower than, equal to, and 2% higher than that required for rod, respectively. This can be attributed to the more homogeneous working in tube extrusions at lower reductions, and greater frictional losses due to tooling configuration at higher reductions.

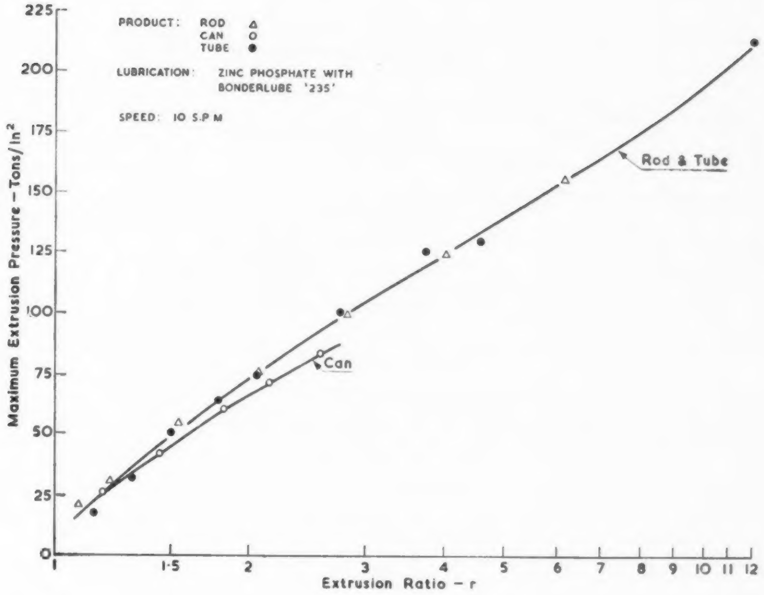


Fig. 18. Effect of reduction on the maximum pressure required to extrude rod, can and tube in En2A steel.

The maximum pressures for the backward extrusion of can were much lower than those for rod, the percentage difference increasing with reduction.

It was of interest to ascertain whether Johnson's relationship

$$p = Y_m \left[1.5 \ \ln \frac{A_0}{A} + 0.8 \right]$$

as discussed earlier, could also be applied to calculate the pressures required to extrude steel at the lower extrusion ratios used commercially.

TABLE 8

Experimental and calculated values of maximum pressure to extrude rod in En 2A steel in a crank press

Extrusion ratio $r = A_0/A$	*ln r*	*Mean strain* $\varepsilon_m = (1.5 \ln r + 0.8)$	*Mean value* Y_m *between 0 and* ε_m *tons per sq. in.*	*Maximum extrusion pressure tons per sq. in.*		*Percentage error using* p_1 *per cent.*
				Value obtained experimentally p *tons per sq. in.*	*Value calculated from* $p_1 = Y_m \varepsilon_m$ *tons per sq. in*	
1.24	0.215	1.123	35.5	30.5	39.9	+30.8
1.56	0.445	1.468	37.0	53.5	54.3	+ 1.5
2.04	0.713	1.870	38.5	77.0	72.0	— 6.5
2.78	1.023	2.335	40.5*	100.5	94.6	— 5.9
4.0	1.386	2.879	42.5*	126.5	122.4	— 3.0
6.25	1.833	3.550	44.5*	158.0	158.0	0

* Extrapolated values.

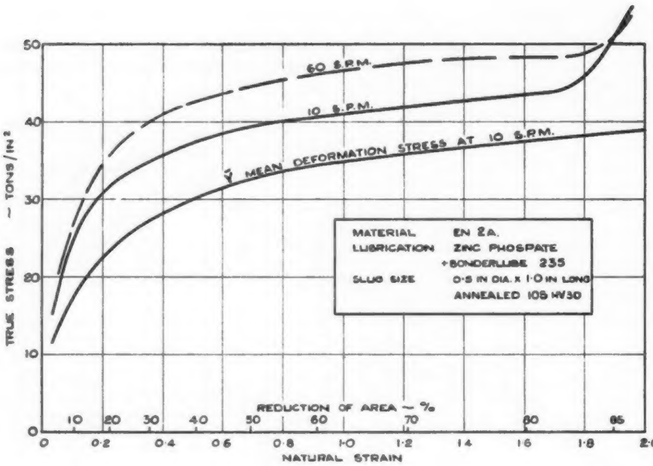


Fig. 19. True-stress/natural-strain curves for plain compression of En2A steel in crank press.

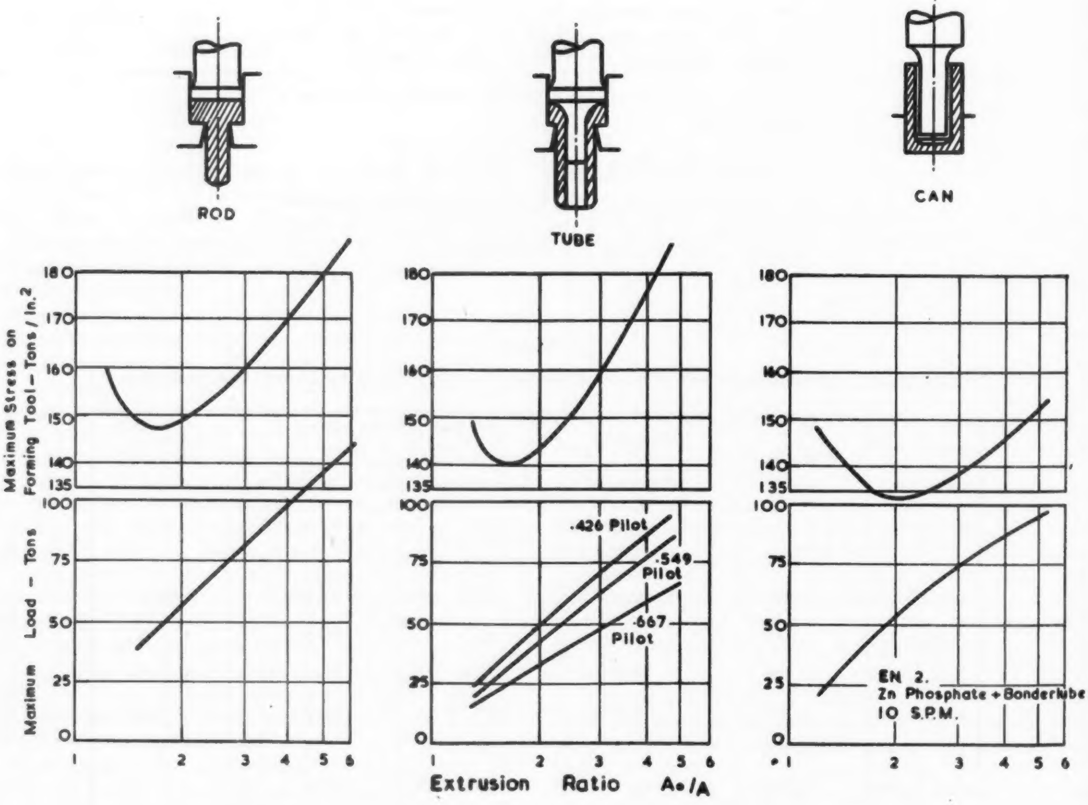


Fig. 20. The effect of reduction on the press load and tool pressure.

Compression tests were carried out in the crank press for slugs of ½ in. diameter and 1 in. long, under conditions of ram speed, and lubrication used during the extrusion experiments. Typical true stress-natural strain curves for the compression of slugs with a zinc phosphate coating and lubricated with Bonderlube 235, deformed at crank speeds of 10 and 60 strokes/in., are shown in Fig. 19. The mean resistance to deformation Y_m at a particular reduction is defined as the mean value of stress over the range of strain from zero to the strain

$$\varepsilon_m = \left(1.5 \ln \frac{A_o}{A} + 0.8 \right)$$

When evaluating Y_m from the true stress curve, the sudden rise of the true stress at the natural strain of 1.8 was ignored since this was attributable to excessive friction caused by the breakdown of lubrication between slug and platens. In the comparison, given in Table 8, of the maximum extrusion pressures calculated from the above expression with the experimentally determined values taken from Fig. 18 for rods, good agreement was obtained except at the lowest reduction.

It is important in the cold extrusion of steel to consider the stresses on the punch and die faces and a comparison of these for the three types of product is given in Fig. 20. The pressure, f, on the die face in the extrusion of rod and tube and on the punch face in the extrusion of can is related to the extrusion ratio, r, and the extrusion pressure, p, by the expression:

$$f = p\left(\frac{r}{r-1}\right).$$

It may be seen from Fig. 20 that both die and punch stresses have minimum values. In the case of cans the minimum value is of considerable importance since the punch stress, f, is usually a limiting factor. The minimum value occurs at an extrusion ratio of 2, which is in agreement with theory. (See Fig. 46, Hill[22]). Theory also predicts that the curve of punch stress against reduction should be symmetrical about the minimum for frictionless extrusion. The minimum values of the die face pressure for rod and tube occur at extrusion ratios slightly less than 2. The values of the die face pressure are greater than the true value since friction at the slug chamber wall takes up some of the load.

For the extrusion of tube, pilot diameters of 0.426, 0.549 and 0.666 inches each cover the same range of reductions when combined with the various dies. As seen from Fig. 20, the pilot diameter did not affect the maximum extrusion pressure over this range of reductions when the lubrication was good. The press load in the extrusion of tube was, however, dependent on the pilot size. Since the outside diameter of the slug remains constant a larger pilot diameter reduces the cross-sectional area of the slug which in turn reduces the press load. Fischer[23] compared the loads required for the extrusion of tubes with those for rods and cans, but this is meaningful only when the original cross-sectional areas of the slugs are the same.

(b) *effect of ram speed*

Ram speeds ranging from 4 to 14 in./sec. have been recommended for impact extrusion,[24] but there are many conflicting views on the influence of speed of deformation on the process. Compression tests carried out in the crank press at 10 and 60 strokes/minute (i.e., impact speeds of 2.6 and 15.7 in./sec.), see Fig. 19, showed that the flow stress was approximately 10% greater at the higher speeds. However, as may be seen from Fig. 21, the same increase in impact speed in the extrusion of rod at a ratio of 4 slightly reduced the maximum pressure. This is in good agreement with Kunogi[25] who found that an increase in ram speed over the range 0.0005 to 2.4 in./sec. reduced the pressure for mild steel by about 6%. It was also found that there was little or no effect of speed on maximum extrusion pressure at other extrusion ratios. It would appear, therefore, that the effect of rate of strain on the flow stress at the higher extrusion speeds is immediately counteracted by the smaller loss of heat by conduction, thereby allowing higher temperatures to be developed with corresponding lower flow stress. The rate of strain and temperature effect virtually cancel out each other.

(c) *the effect of chemical composition on maximum extrusion pressure*

The resistance to deformation of a given steel in the annealed condition is dependent upon its chemical composition. In order to be of value to the practical engineer, it is essential to ascertain which steels can

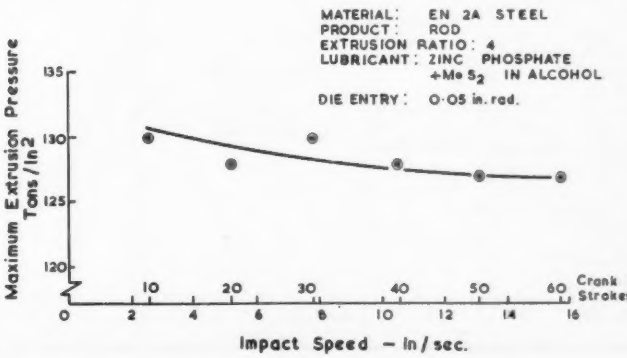


Fig. 21. Effect of extrusion speed on the extrusion pressur..

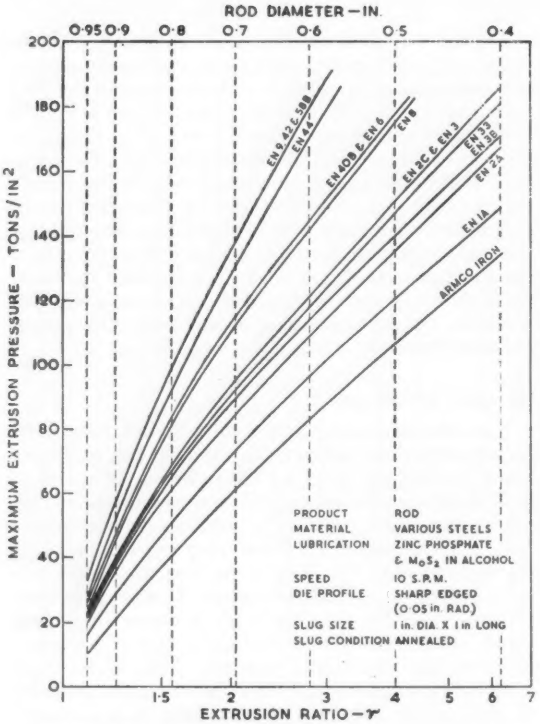


Fig. 22. Effect of reduction on the maximum extrusion pressure required for various steel rods.

be successfully cold extruded and to determine the manner in which the extrusion pressure is influenced by chemical composition.

For this investigation rods and cans were extruded through sharp entry dies in a crank press at 10 strokes/min. (i.e., an impact speed of 2.6 in./sec.) from plain carbon and alloy steels using molybdenum disulphide as lubricant. For the extrusion of cans, steels of carbon content up to 0.24% and up to 1% manganese were used, while in the case of rods, the whole range of steels was used. The chemical analysis, heat treatment and mechanical properties of the steels are listed in Table 7, the yield point and ultimate tensile strength of steels being determined from tensile tests in a Hounsfield tensometer. The maximum extrusion pressures for rod are shown in Fig. 22 as a function of extrusion ratio. The individual points are omitted for clarity but each curve is based on the results of at least 25 extrusions. The scatter in the results for all steels was ±5% except in the case of steel En58B where the figure was ±8%.

It is clear that the curves in Fig. 22 cannot be represented by an expression of the form $p = a \ln \frac{A_0}{A} + b$, as was done in the case of non-ferrous metals.

However, since the lines in Fig. 22 are only slightly curved, each can be represented by 2 such relations over different ranges of extrusion ratio. This has been done in Table 9 where the appropriate values of a and b for each steel over 2 ranges of extrusion ratio are given.

TABLE 9

Values of constants a and b in the expression $p_0 = a \ln r + b$ for the pressure required to extrude plain carbon and low alloy steels under specified conditions

Steel	*Product*	*Lubrication*	*Die or punch profile*	*Values of constants a and b*			
				1.15<r<1.8		*r = or >1.8*	
				a_1	b_1	a	b
En 2A	Rod	Zinc phosphate and Bonderlube 235	Sharp edged (.05 in. radius edge)	83.7	9.0	73.6	23.0
En 2A	Tube	Zinc phosphate and Bonderlube 235	Sharp edged (.05 in. radius edge)	102.4	4.0	79.3	23.0
En 2A	Can	Zinc phosphate and Bonderlube 235	Sharp edged (.05 in. radius edge)	84.7	11.0	61.4	23.0
En 1A	Rod	Zinc phosphate and Bonderlube 235	Sharp edged (.05 in. radius edge)	78.0	11.0	63.0	20.0
En 1A	Can	Zinc phosphate and molybdenum disulphide in alcohol	1 in. radius chamfer	82.3	14.0	56.3	30.0
En 2A	Can	Zinc phosphate and molybdenum disulphide in alcohol	1 in. radius chamfer	83.1	15.0	63.6	27.0
En 3B	Can	Zinc phosphate and molybdenum disulphide in alcohol	1 in. radius chamfer	89.5	14.0	59.2	34.5
En 3	Can	Zinc phosphate and molybdenum disulphide in alcohol	1 in. radius chamfer	101.0	14.0	82.0	27.0
En 32B	Can	Zinc phosphate and molybdenum disulphide in alcohol	1 in. radius chamfer	89.5	14.0	59.2	34.5
Armco iron	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	87.4	1.0	65.3	15.0
En 1A	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	88.0	11.0	69.5	22.5
En 2A	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	92.4	15.0	77.0	25.0
En 2C	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	125.7	11.0	80.0	39.0
En 3B	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	114.0	11.0	75.4	35.0
En 3	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	125.7	11.0	80.0	39.0
En 6	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	150.0	15.0	93.0	48.0
En 8	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	146.0	15.0	91.0	48.0
En 9	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	177.5	17.0	139.5	39.0
En 32B	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	114.0	11.0	75.4	35.0
En 33	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	164.5	16.0	126.7	36.0
En 40B	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	150.0	15.0	93.0	48.0
En 42	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	177.5	17.0	135.0	39.0
En 44	Rod	Zinc phosphate and molybdenum disulphide in alcohol	Sharp edged (.05 in. radius edge)	164.5	16.0	126.7	36.0
En 58B	Rod	Bonderite 'SS' + M_0S_2 in alcohol	Sharp edged (.05 in. radius edge)	177.5	17.0	135.0	39.0

The effect of increasing the carbon content of the steel was obtained approximately by comparing the extrusion pressures at a given extrusion ratio for a number of steels of different carbon content but whose composition was otherwise the same. The same thing was done to assess the effect of manganese content. It appeared that carbon was approximately 4 times as effective as manganese in increasing the maximum extrusion pressure. Some idea of the absolute effect of these elements may be obtained from the fact that for steels with a carbon and manganese content up to 0.8% and 1.2% respectively, the maximum extrusion pressure at an extrusion ratio of 5 may be represented by:

$$p = 126C + 32\ Mn + 120$$

where p is in tons/sq. in., C and Mn are the percentages of carbon and manganese in the steel to be extruded.

The addition of up to 3% nickel or 3% chromium did not increase the required extrusion pressure significantly, the increase being less than 10%.

It should be noted that steel En44 containing 1.03% carbon gave a lower maximum pressure than steel EN42, containing 0.78% carbon. Although the extrusion pressure for En44 cannot be represented by the above empirical formula, it is consistent with the effect of carbon content on the tensile stress of annealed steels as seen in Table 7.

The increase in extrusion pressure for an increase in carbon content from 0.16% to 0.47% was found in the present investigation to be 27%. This compares with 30% found by Hauttmann[26], 15% by Feldmann[27] and 56% by Perry[28] for the same increase in carbon content.

No difficulty was experienced in extruding any of the steels tested except En54 and En58B. Rods in En54 (0.4% C, 14% Cr, 14% Ni) showed circumferential cracking when extruded at a ratio of 1.24 and the die aperture was badly eroded. Whilst the austenitic steel, En58B (0.13% C, 19% Cr, 9% Ni) was successfully extruded at ratios up to 2.78, longitudinal cracks occurred in the rod at the ratio of 2.78. Similar cracking was observed by Kunogi[25] during the extrusion of austenitic steel using special tooling arrangements.

Hardness readings taken at intervals of 0.025 in. across the polished mid-sections of rods, tubes and cans after extrusion showed that the maximum hardness was found nearest to the edge of the tool producing the deformation, i.e., the bore of the can and the surface of the rod and tube, and that its value was not greatly influenced by reduction as was also found in the case of non-ferrous metals.

The effect of reduction on the mean hardness through the section of rod extruded from different materials at 10 strokes/min. (except for En16 where

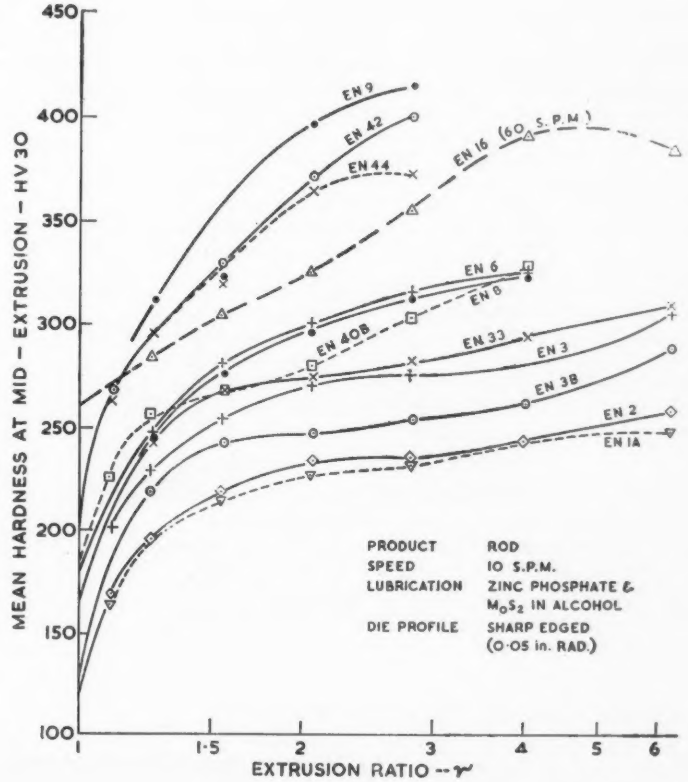


Fig. 23. Effect of reduction on the mean hardness of rods extruded from various steels.

the speed was 60 strokes/min.) is shown in Fig. 23. It is clear that the plain carbon steels harden proportionately more than the alloy, an extrusion ratio of 2.78 (i.e., a reduction of 64%) increasing the mean hardness of low carbon steels by a factor of 2. For a ratio of 6.25 (84% reduction) the mean hardness of En2A steel increased $2\frac{1}{2}$ times, the hardness through the mid-section of the product ranging from 246 to 275 HV30.

The slow increase of hardness of mild steel in the range of extrusion ratio of 1.5 to 3.5 agreed with that found by Ebert [29] in tube drawing.

the application of extrusion data to process design

Whilst the research effort has been generally concentrated on the derivation of data on the cold extrusion of the three basic types of product in a range of metals rather than on the specific investigation of the production of individual engineering components, it is clear that the same general principles apply and the data obtained can be used in the consideration of the production of specific engineering components giving the required information on press loads and tooling stresses at each stage of the process.

As an example of the application of the above data, consider the manufacture by cold extrusion of a steel tubular component of 0.5 in. bore, 2.5 in. length and 0.1625 in. wall thickness from round bar. The dimensions prevent the manufacture of the component in one operation by the backward extrusion of a can from a solid slug since this would require too slender a punch (length to diameter ratio in excess of 5). A three-stage operation is therefore considered and is illustrated in Fig. 24, the first stage being essentially a sizing operation for the sawn-off slug.

In stage 1 the sawn-off, cropped or parted off bar is given a sizing operation in which the ends of the slug are made perpendicular to its axis and shaped by slight upsetting to facilitate subsequent operation as shown in Fig. 24.

In stage 2 the slug is backward extruded to form a thick-walled can (E) whose bore is the same size as that required on the final tubular component. The bottom of the can is made to the required thickness, or if this is not specified it is made as thin as the tooling stresses and the avoidance of surface defects permit.

In stage 3 the can is forward extruded using a mandrel or pilot (F) to govern the size of the tube bore, the mandrel being of the same diameter as the punch nose (K) used in stage 2. The outside diameter of the tubular component is fixed by the bore of the die (H) which is supported by a backing ring. A straightener (J) may be added to ensure that the extruded tube is straight.

The design of tools clearly requires care. Thus, for example in stage 2, it is important that the punch be adequately guided, its length to diameter ratio kept as small as possible to obviate a tendency to buckle and the punch stress kept to a reasonable figure. This latter aspect presents difficulties since as was seen from Fig. 20, the punch stress remains sensibly uniform over a fairly wide range of extrusion ratio and is therefore primarily dependent on the properties of the material being extruded.

The method of procedure is as follows. Since there is no volume change in plastic deformation, the volume of the material in the component is calculated and this determines the volume of the slug required. The punch diameter for stage 2 is determined solely by the bore of the tube and so the first problem is the determination of the diameter of the slug. If the diameter of the slug is small, the reduction

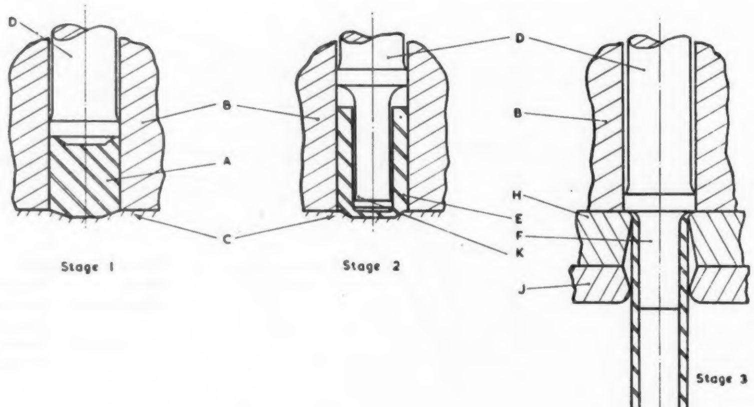


Fig. 24. Three stages in extrusion of tubular shapes.

in area in stage 2 will be large, demanding a correspondingly high extrusion pressure and a high punch stress. Further, a comparatively long can will be produced necessitating the use of a long slender punch with an increased tendency to buckle. However, the subsequent extrusion in stage 3 would be relatively simple involving only a small reduction and a low extrusion pressure. On the other hand, if the initial diameter of the slug is large, only a small reduction would be produced in stage 2 requiring a low extrusion pressure, although as seen in Fig. 20, this may still require a reasonably high punch stress. A flat, thick-walled can is produced which would require in stage 3 a very large reduction and consequently a very large extrusion pressure and punch stress. Thus, the aim is to choose an external diameter of the slug such that the extrusion pressures required in stages 2 and 3 are approximately the same, consistent with the fact that the length to diameter ratio of the punch is small and that the punch stress is not excessive.

It is necessary to decide on the diameter of the slug to be used, and for the component considered 1 in. seems a convenient first-estimate for this dimension.

(i) Stage 2 now becomes the extrusion of a can of 1 in. outside diameter and 0.5 in. bore, that is, at an extrusion ratio of 1.33. The corresponding value of the maximum pressure required to extrude these cans in a range of materials can be determined from the appropriate extrusion pressure—extrusion ratio curves for rods given in Figs. 9 and 22. For copper, brass 70/30, steel En1A and steel En8, these values are 17, 25, 32 and 58 tons/sq. in. For steel En1A the extrusion load is therefore $32 \times \frac{\pi}{4} \times 1^2 = 25.9$ tons. The punch stress is obtained directly from the extrusion load and the value is 133 tons/in.^{2} Having determined the punch stress it remains only to check its slenderness ratio from the geometry of the extrusion, and in this case has a value of 3.

(ii) Stage 3 is now the extrusion of a tube of 0.825 in. outside diameter and 0.5 in. bore from a slug of 1 in. outside diameter and 0.5 in. bore, that is, at an extrusion ratio of 1.74. As before, the corresponding values of the maximum pressure required to forward extrude tubes in the different metals can be determined from the appropriate extrusion pressure-extrusion ratio curves. The required maximum extrusion pressure for steel En1A is 62 tons/sq. in. Therefore the extrusion load is $62 \times \frac{\pi}{4}\left[1^2 - (0.5)^2\right] = 36.5$ tons.

Now the extrusion pressures in the two stages could be made equal by using an initial slug diameter greater than 1 in. However, in this case, stage 3 is such a straightforward extrusion with moderate reductions and tool stress that it is preferable to reduce the high punch stress occurring in stage 2. This can be done by starting with an initial slug diameter of less than 1 in., i.e., by increasing the extrusion ratio above 1.33 towards the value 2. However, as may be seen from Fig. 20, the reduction that can be obtained in punch stress is limited.

This minimum stress to which the punch can be subjected in the extrusion of cans from slugs of 1 in. diameter is dependent on the material, and approximate values deduced from the values obtained for rods in Fig. 22 for a range of steels are given below.

Steel	*Armco Iron*	*En1A*	*En2A*	*En3B*	*En33*	*En3*	*En8*	*En40*
Minimum punch stress tons/in^2	105	130	142	154	157	163	192	197

It will probably be necessary to incorporate a straightener in stage 2 to ensure that all products are straightened during the extrusion. The presence of a pilot will greatly assist in producing concentric tubes and it will only be necessary to ensure that this is given an adequate radius in blending it into the punch base. A sharp corner in this position will inevitably result in the pilot failing in tension during withdrawal.

It will be noted that the basic extrusion pressure-extrusion ratio data used in the above calculations were obtained for the extrusion of rods, cans and tubes from fully annealed slugs of length/diameter ratio of 1. If the ratio for the slug required for the particular component as determined above is significantly less than 1, then the values of the maximum pressure are somewhat reduced.

The appropriate relationship is already available from the earlier study of the effect of slug geometry on the extrusion pressure. The data for tubes strictly referred to the extrusion of slugs with machined bores. Additional tests, however, have shown that tubes extruded from cans required higher maximum pressures when the latter were in the "as extruded" condition. When the cans were re-annealed prior to extrusion into tubes, the maximum pressures were not significantly different from those required to extrude bored slugs.

A variation in crank speed over the range of operating speeds normally available in commercial crank presses is unlikely to influence the maximum extrusion pressure to any significant extent. The effect of different lubricants over this range of conditions is also likely to be small.

acknowledgements

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APPENDIX and REFERENCES OVERLEAF

APPENDIX

Definitions and Nomenclature

d_0 — die aperture diameter (in.)

D_0 — extrusion chamber diameter (in.)

d_1 — pilot diameter (in.)

d_2 — punch diameter (= can bore) (in.)

A — cross-sectional area of final product (in.^{2}), which was assumed to be that of the die aperture.

A_0 — cross-sectional area of original slug which was assumed to be that of the extrusion chamber. (in.^{2})

L — Press load (tons)

p — extrusion pressure (tons/in.^{2})

r — extrusion ratio

R — reduction of area

f_3 — normal stress on bearing area of pilot

f_2 — punch stress in extrusion of cans (tons/in.^{2})

f_1 — normal stress on die face in extrusion of tubes (tons/in.^{2})

f_0 — normal stress on die face in extrusion of rods (tons/in.^{2})

Extrusion Ratio $r = \frac{A_0}{A}$

Reduction of area $R = \frac{A_0 - A}{A_0}$

where $A_0 = \frac{\pi}{4} D_0^2$ for rods and cans

$= \frac{\pi}{4}(D_0^2 - d_1^2)$ for tubes

$A = \frac{\pi}{4} d_0^2$ for rods

$= \frac{\pi}{4}(d_0^2 - d_1^2)$ for tubes

$= \frac{\pi}{4}(D_0^2 - d_2^2)$ for cans

Extrusion pressure

$$p = \frac{L}{A_0} \text{ tons/in.}^2$$

Stress in punch $f_2 = \frac{4L}{\pi (d_2)^2}$

Normal stress on die face in extrusion of rods and tubes:

$$f_0 = f_1 = \frac{4L}{\pi(D_0^2 - d_0^2)}$$

Normal stress on bearing area of pilot

$$f_3 = \frac{4L}{\pi(D_0^2 - d_1^2)}$$

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BASIC FEATURES OF THE COLD FORGING PROCESS

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THE ubiquitous woodscrew and the rivet are typical products of the mass production cold forging process — a process where the starting material is usually round wire and the forged components are formed continuously at relatively high rates of output. The components in general have axial symmetry but forging is really a process whereby a change is made to both the physical features and the physical properties of a component without changing its weight. A study of modern cold forging techniques will show that it is a process well suited for the manufacture of many kinds of components which are currently made by other methods.

Unfortunately, cold forging is a process in which practical development has proceeded at a faster rate than the basic research work has followed and there is a scarcity of published technical information on the subject. As a result, cold forging is still largely an art rather than an exact science.

Mr. Cooper was educated at King Edward VI High School, Birmingham, and served with the R.A.F. during the War as a bomber pilot. He gained a B.Sc. degree in Mechanical Engineering at the University of Birmingham in 1951.

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In 1956 Mr. Cooper was granted the Birmingham College of Technology Associateship in Industrial Administration, and in 1958, studied Industrial Engineering at Columbia University, New York.

Perhaps it is because of this state of affairs that designers and engineers have tended to neglect the potentialities of the process, through a lack of knowledge of the type of plant used and the basic features which affect a design for cold forging.

Historically, although the industry is well over 100 years old, there appear to have been only slight changes in the type of product produced by the industry up to the First World War. Under these conditions, the man on the job was able to familiarise himself with his raw materials, his tools and his machines to the extent of being the master of all his trades. Also, due to the industrial conditions prevailing at the time, this " know-how " tended to be retained as trade secrets and, as a result, the consumer had to be content with the type of products which the industry wished to offer. It was not until the Second World War that, due to a radical change in customer demand, real studies were made of the cold forging process. Thorough investigations were made of the capabilities of the recently introduced solid die forging machines and the potentialities of the more advanced forms of tool steels. The net results were that a wider variety of materials for cold forging became available, tool making became a separate and highly specialised function and higher standards of machine setting were achieved. To a certain extent, the customer now determines the products made by the industry.

Hence, this Paper is intended, for those unacquainted with cold forging, to be an introduction to the basic features of the process and to provide some information on the elements of design for it.

To make the maximum use of the process it is necessary to consider:

(a) the limits of practicality of existing machines; alternatively, if the product warrants it, the necessity for developing specialised machinery;

(b) the value to the consumer of obtaining shapes and physical properties which could only be obtained otherwise by more expensive methods; (it must be noted that the cost of forging is not necessarily the cost of the cheapest route—the

value to the consumer of the end product should be the deciding factor);

(c) the raw material to be used — the upper limit to the strength of the material to be forged is largely set by the strength of the tool material;

(d) the final specifications of the product which either determine or are determined by the type of plant available.

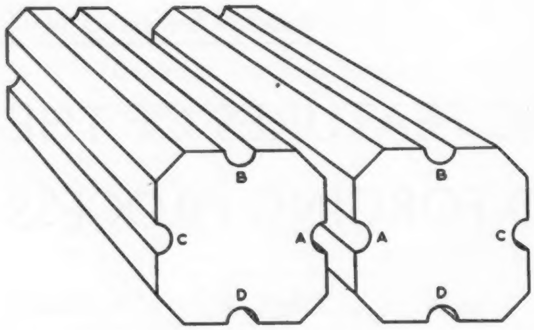

Fig. 1. A pair of split dies showing their matching semi-circular grooves extending down the whole length of the die.

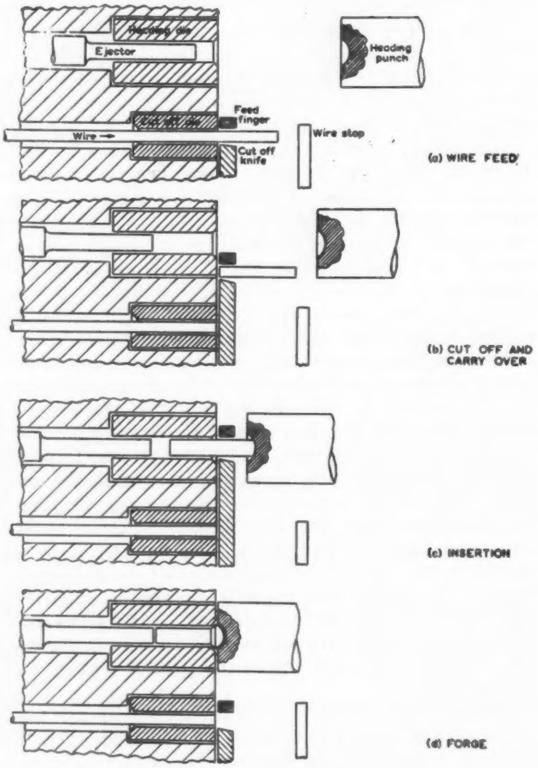

Fig. 2. Sequence of operations of a single blow solid die header.

cold forging machines

Special purpose horizontal mechanical presses are used for cold forging. Although these machines, fitted with automatic feed and cut off, are known as cold-headers, the term is misleading, as it is possible to upset portions of the shank of the wire in addition to forming the head.

There are several basic types of forging machines and these can be classified according to the following characteristics:

1. *The type of heading die.*
   Two die types are recognised and each requires a specific machine design. The split die header, which is known also as the open die header, uses a die made up from a pair of rectangular blocks, each with matching semi-circular grooves extending down the length of the block (see Fig. 1). The solid die header uses a die which is a simple cylinder with a hole extending down the longitudinal axis; more normally, this die will be made up from a pre-stressed cylindrical case and an insert.

2. *The number of heading blows available within the cycle of operations.*
   The majority of cold-headers are either single blow or double blow machines. A single blow header applies the heading punch once during the cycle, i.e., a component is forged for each stroke of the punch ram. The double blow header, fitted with an indexing punch holder containing two separate punches, applies each of the punches once during the cycle, i.e. two complete strokes of the ram are required to produce one component.

   There are few machines which have been designed to provide three blows—three punches but three revolutions of the flywheel per component. This type of machine is not in common use, as the decreasing ductility of the upset material tends to reach a limiting figure when forging with a single die. Due to this limiting factor, a modified form of header, known as a transfer header, has been developed. This machine is, in reality, a series of single blow, single die headers, each linked to the next by means of a transfer mechanism, and all contained within one frame. Thus, this convenient arrangement of dies permits a progressive reduction of the wire diameter to be undertaken and the multi-tool arrangement allows more complex forms to be achieved. As each operation is carried out simultaneously, a finished component can be produced with every stroke of the header.

3. *The maximum diameter of wire which can be used on the particular header.*
Cold heading machines are designed to operate within certain specified wire diameter ranges and it is common for a machine to be known by the maximum wire diameter it can handle and not by its available power, e.g. $\frac{1}{8}$ in., $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{5}{16}$ in., $\frac{3}{8}$ in. and $\frac{1}{2}$ in. The design limitation is not only in the available power, but it is also in the size of the die pockets and the strength of the cut-off mechanism.

4. *The maximum length of wire which can be cut off at each cycle of operations.*
Heading machines are designed also to operate within specified lengths of cut-off. (It should be noted that the cut-off length includes all the material to be upset into the head as well as the material to form the shank.) Thus, for every machine, there will be an absolute minimum and an absolute maximum cut-off length and the resultant shank length will be dependent upon the volume of material which is to be upset into the head. As a general rule, the minimum cut-off length is considered to be about three times the wire diameter and for solid die forging, a maximum about 12 times the wire diameter. However, special long-stroke machines are designed to operate between roughly eight times wire diameter up to 20 times wire diameter.
It will be shown later that the split die header can be capable of handling a cut-off length of up to 30 diameters.
Exceptionally long work is usually forged in specially designed open die headers, sometimes known as spoke headers, where the frame is cut away to facilitate either manual or semi-automatic feeding.

cold forging sequence of operations

The basic sequence of operations is essentially the same for all types of headers but as there is a difference between the operation of a split die and a solid die header, both sequences are described here.

solid die header

In the case of a single blow solid die header (see Fig. 2), wire is fed from the coil by automatic feed rolls, through a cut-off die, up to an adjustable stop. The stop is so arranged as to cause a predetermined length of wire to protrude in front of the cut-off die. A cut-off knife slides across the face of the cut-off die and shears off the predetermined length of wire; the slug is retained in the knife, by a hinged finger. The motion of the cut-off knife is continued so as to transfer the slug to a position in line with the heading die bore. The heading punch is advanced and pushes the slug part-way into the die, i.e. until the insertion is prevented by a plunger prepositioned inside the die bore. The cut-off knife and finger in the meantime have released the slug and they return to a position in front of the cut-off die.

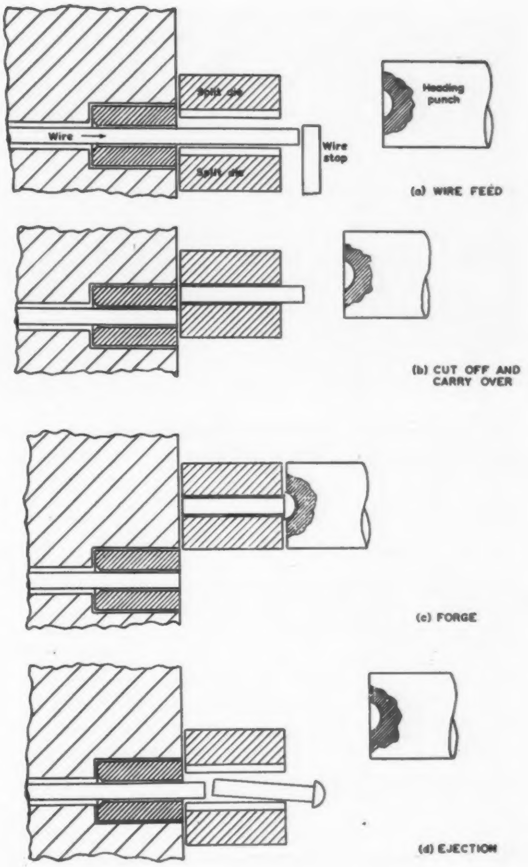

Fig. 3. Sequence of operations of a single blow split die header.

The prepositioning of the plunger causes a determined amount of the slug to remain protruding in front of the die and it is this portion of the slug which is upset by the continuing forward motion of the heading punch. Initially, the whole of the compressive force is exerted on the end of the plunger but, as soon as the slug begins to upset, the thrust is distributed across the newly formed surfaces against the face of the die. Any tendency for the shank to swell and bind in the bore of the die is thereby limited.

On some machines, relieving attachments are used to withdraw the plunger along the die after the slug has been located, so that any tendency for the shank to buckle or for the end of the shank to swell is prevented.

Consequently the wire is formed to the shape of the cavity in the heading punch and/or in the face of the die. The heading punch is withdrawn and the plunger is caused to move forward, thereby ejecting the headed blank from the die.

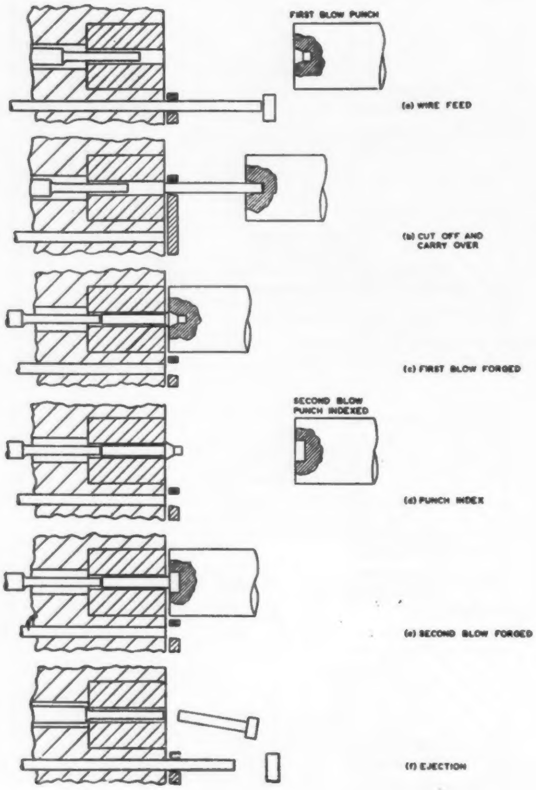

Fig. 4. Sequence of operations of a two-blow solid die header.

With this arrangement, components having the same head form and shank diameter, but different plain shank lengths, can be accommodated by adjusting the amount of wire cut-off and also the position of the plunger in the die bore within the design limits of the header.

In other words one simple tool will accommodate a wide range of lengths; hence cheaper products result from a standardisation to common shank diameters.

The maximum slug lengths which can be fed into a " closed " die and, after upsetting, ejected from the die is normally equivalent to about 12 wire diameters. The length is limited not only by the functional forces involved but also by the relative clearances around the various moving parts at the carry-over, feed and ejection stages in the cycle.

split die header

The split die header uses a die made up of two rectangular blocks, so arranged that one block can be moved a small distance laterally relative to the other (i.e. the die can be opened slightly at the beginning and at the end of the cycle) and the die as a whole can be moved laterally relative to the machine frame (see Fig. 3).

In the case of the single blow split die header, wire is fed from the coil in between the blocks in their open position (i.e. from the rear of the blocks) up to an adjustable stop. The die blocks then close, the movement of one block towards the other shears off the predetermined length of wire and then clamps the slug. It should be noted that the rear face of the block acts as the cut-off knife. The die as a unit continues to move laterally to bring the slug in line with the punch and, at the same time, to bring the rear face of the die in front of a solid portion of the frame. The punch then moves forward to upset the protruding portion of the slug. As the punch withdraws the die returns to the starting position and the blocks separate slightly. Thus, as the wire is fed in for the next cycle, the end of the wire acts as an ejector for the headed blank.

It will be seen that with the split die header, each shank length requires a specific length of die due to the fact that the rear face of the die registers the end of the shank. However, since the split die is open during wire feed in and during ejection, the length is limited only by the machine design (and by the ability to pre-straighten the wire).

It should be noted that, although a powerful clamping mechanism is used, the characteristic feature of the split die header is the slight witness of the division between the two die blocks on the under-surface of the head of the blank. The blocks tend to wince, or separate, slightly under the full heading load and material is forged into the gap.

The advantages of the split die header are that:

(a) there is a minimum of trouble ejecting long work;
(b) there is a minimum of tool wear as a result;
(c) the shank diameter of the blank can be maintained very closely over the whole length of the blank.

two-blow machines

With the two-blow machines (see Fig. 4), the sequence of operations is as described above except that the blank is retained in the die after the first blow has been applied. As the first heading punch is withdrawn, the punch block is indexed so as to bring the second heading punch in line with the die. The second blow is applied and the blank ejected in the normal manner. The wire feed and cut off mechanism is arranged to operate only once during the cycle.

transfer headers

In the case of transfer headers, the design is based on the solid die method. These machines are sometimes called progressive headers as the blank, after each forging stage, is ejected into transfer fingers and carried over to the next station. Thus a number of head forging and/or shank reducing operations can be carried out simultaneously and a finished component is produced at each stroke of the machine. It is usual for the machine to have three, four or five forging stations and the final station can be

Fig. 5. A single blow solid die header, without tools, showing the relationship between the centre line of the cut-off die and the centre line of the heading die.

Fig. 6. A two-blow header punch block shown without tools to indicate the limited space available for the punches.

adapted to trim, or shear, a cheese-headed blank to a square or hexagon form.

limitations of forging machine design

In principle, cold forging machines are special purpose horizontal presses; in fact, these machines are quite different in order to achieve high speed production. The masses of the moving parts have to be reduced to their functional minimum and the distances through which these parts are moved must be minimised. As a result, forging machines tend to be compact with free space at a premium and each particular machine will have certain basic limiting features:

1. the length of cut-off slug;
2. the timing of the carry-over mechanism with the advancing/retarding punch ram. "Timing" in this context concerns the acceleration and deceleration of the mechanism within very limited periods of time determined by the punch ram motion;
3. the size of the tool pockets which limit the strength of the tools used (see Figs. 5, 6 and 7);
4. the length of ejection from the die.

Conventional machine design uses the die as the datum and alignment of tools is made by adjusting all the tools relative to the die. The confined spaces within the machine frame are usually so constructive as to eliminate any possibility of having finite tool adjustment controls, i.e., final alignment is dependent upon the skill of the machine setter.

Mass production high speed machines necessitate having mass production tolerances and the accuracy of the finished product, under continuous running conditions, is dependent upon:

1. the wire tolerance — usually .002 in.;
2. the tool manufacturing tolerances — .005 in.;
3. the tool setting tolerances — human skills;
4. the elasticity of the tool assemblies (especially the die)—on a $\frac{3}{16}$ in. machine a deflection of up to .0015 in. can be expected at a position close to the die mouth;
5. the clearances between the ram and the ram guides — usually .0015 in. - .0025 in.;
6. the cumulative clearances in the various punch shifter mechanisms of multi-blow machines.

It should be noted that there is a characteristic feature in the cold sheared cut-off slug from a normal mass production cold forging machine. This feature is the slightly deformed sheared end which is still present even after the forging operation. One solution to this undesirable feature is to be found in the latest machine design where a totally enclosed cut-off knife is used to minimise the shear effect.

Current designs of cold forging machines include the rotating multi-die block system in an attempt to

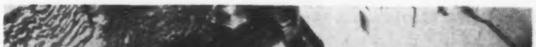

Fig. 7. The type of punch block fitted to a transfer header.

increase the potential output from the machine. This design has the inherent problem of locating accurately the indexing parts. The effect of any misalignment of any one punch tends to be cumulative not only on the other punches, but also on the progressively formed blank.

cold forging limitations

upset ratio

As the upsetting force is an axial compression, there is a limited length of unsupported wire (protruding from the die) which can be upset at the beginning of the process without buckling, i.e. this is a classic example of the Euler Theory of Struts. For successful forging the material must upset evenly and flow in controlled directions; properly controlled grain flow is the factor chiefly responsible for the superior strength of cold forged components compared with components produced by machining from bar stock. Thus, one of the important factors to be considered, when assessing a component for its "forgeability", is the upset ratio. This is the ratio between the length of wire required for upsetting into the head shape to the original diameter of the cut-off wire. As the ratio is increased, there is an increased tendency for the wire to buckle and, as a consequence, unsatisfactory grain flows will be obtained within the finished forged head.

Practical experiment indicates that the maximum possible length which may be upset in one blow cannot normally exceed 2.3 times the wire diameter.

If it is required to upset ratios greater than 2.3, and not more than 4.5, the total upset must be shared between two blows. Clearly the second punch and the die form must correspond exactly to the size and shape of the finished component; the shape of the first blow punch being determined by the needs of the process and not by the design requirements of the finished shape.

It is usual for the first blow punch to be designed so that it gathers the wire into an approximately conical form (see Fig. 8). The design of this conical form tends to be critical, but the principle is to support part of the wire in the back of the punch and to start the material swelling outward so that, when the finished punch is applied, the material will continue to flow in the desired direction.

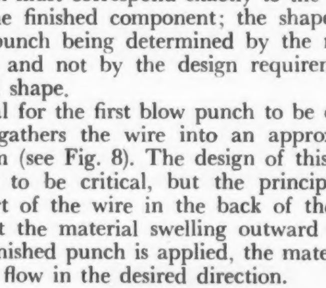

Fig. 8. A typical coned first blow form and the resultant second blow form.

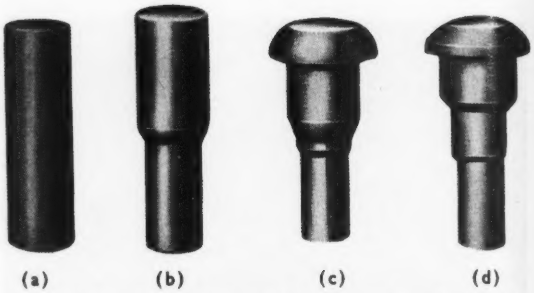

Fig. 9. A typical sequence of blanks from a transfer header. The sequence shows: (a) cut-off slug squared off in the first die to remove irregularities in the end of the sheared blank; (b) first extrusion in the second die; (c) second extrusion in the third die and the head partially formed; (d) final extrusion in the fourth die and the head finished forged.

The upset ratio is influenced by the practical design of the finished shape and the achievable ratio may be less than the theoretical maximum—for example, large diameter heads and non-concentric heads, due to the manner in which the material will flow. To a smaller extent, the ratio will be influenced by the surface condition of the wire, and the lubricant which can be used, when the effect of imperfections (for example, any tendency to cracking) imposes physical limitations on the amount of the upset.

As three-blow headers are not commonly found, it is usual to obtain upset ratios of greater than 4.5 by partially forming the head shape on a standard two-blow header and then finish forge on a reheader. A reheader is a normal header adapted for magazine feed; this arrangement permits any inter-process annealing which may be required for these larger upsets. An alternative method of obtaining upset ratios of greater than 4.5 is to forge on a transfer header but, in this case, it is usual to use wire stock of a larger diameter than for the two-blow/reheader method (see Fig. 9). The use of a larger wire diameter will reduce the actual working upset ratio and the transfer header tool arrangement permits the larger diameter to be reduced to the final desired shank diameter.

Difficulties are encountered when forging very low upset ratio heads (i.e. heads with only a small degree of deformation) since the small force required for upsetting may be insufficient to remove irregularities in the cut-off slug. Additionally, any volumetric variation in the cut-off slug will be reflected to a greater degree in heads of small volume.

Larger diameter thin heads tend to provide the worst forging conditions. There is always the tendency for material to burst in the regions of maximum displacement, i.e., around the outer circumference and it is usually seen in the form of peripheral cracking (see Fig. 10). This is especially so when there are discontinuities in the surface of the original wire, e.g., wire-drawing scores, laps and surface slag. In addition, the actual deformation of material tends to be non-uniform. (It will be seen, therefore, that cold

forging also tends to act as an automatic inspection operation for flawed material.)

For example, expansion becomes non-uniform due to the friction of compressed surfaces and to the internal effects of material work hardening. These factors can be minimised by reducing the compressive surface friction (by effective lubrication) and by selecting material which has a good surface finish free from inclusions. Thus, where the component shape requires large mean deformations the material should be capable of good deformability, but if the component shape requires high maximal deformations, then the material must have a good surface finish, i.e. there is a definite relation between material stress and material content.

Hence the degree of deformation (the ratio of the cross-sectional area of the upset part to the cross-sectional area of the original wire) must be taken into account as well as the upset ratio. The degree of deformation can be conveniently expressed as a logarithmic relationship, i.e. $\log_e A1/Ao$. When the value for $\log_e A1/Ao$ approaches a limiting value of about 2, normal two-blow methods produce unsatisfactory deformations and it is necessary to resort to transfer header methods.

An example of how this criterion can be used is given here (see Fig. 11). On a two-blow machine the starting material is shank diameter (Ao) and the wire is extruded to thread rolling diameter (A1) while the head is forged to a cheese shape. If the degree of deformation of the unextruded portion of the shank is zero, the value of $\log_e A1/Ao$ for the head is about 1.5 and the value for the extruded shanks is about 0.25. By re-routing to a transfer header, the starting material can be larger than shank size. At the first station a portion of the slug is extruded to shank size; at the second station a portion of the extruded shank is re-extruded to thread rolling diameter while the head is forged from the original wire diameter to a cheese shape. The degree of deformation for the head is about 1.2, for the plain shank is about 0.4 and for the thread rolling shank the value is about 0.6. Hence the head is less work-hardened and the degree of work hardening over the whole blank has been made more uniform.

It is possible by this type of re-routing to produce satisfactory components without resorting to inter-process heat treatment.

length

There are three dimensions along the longitudinal axis which must be considered—the overall length of the finished component, the length of the part of the component in the die and the cut-off length. These must not be confused. The minimum length in the die should not be less than approximately the wire diameter in use, but this is dependent upon the head volume and the head style.

This limitation is due to :—

(a) the difficulty of holding a relatively short length of slug in front of the die for sufficient time to allow the wire to enter the die (and thus be located) and yet permit the carry-over mechanism to withdraw in time to avoid contact with the advancing punch. The usual remedy is to employ an especially thin cut-off knife and carry-over finger but this tends to give an insecure grip of the cut-off slug;

(b) the frictional forces between the die bore and the parallel part of the shank in the die tend to a minimum and to be less than the frictional forces between the wire and punch. There is then a tendency for the punch to pull the blank from the die and so cause a jam. Various devices are employed to defeat this tendency; for example, the bore of the die can be "ringed" so that shank material is forged into the ring and causes a lock to occur between the shank and the die. Alternatively, a positively ejecting punch block can be used; in this method the

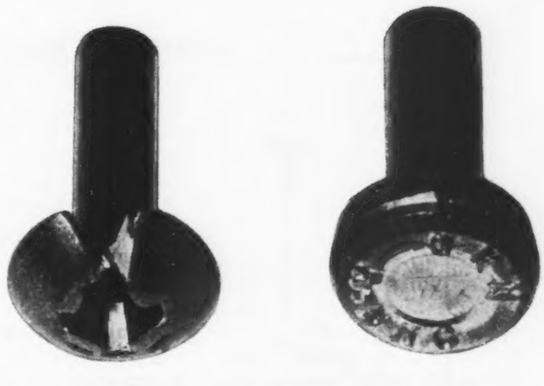

Fig. 10. Example of forged heads exhibiting peripheral cracking. It can be seen that the forging operation offers a remarkably effective form of automatic inspection.

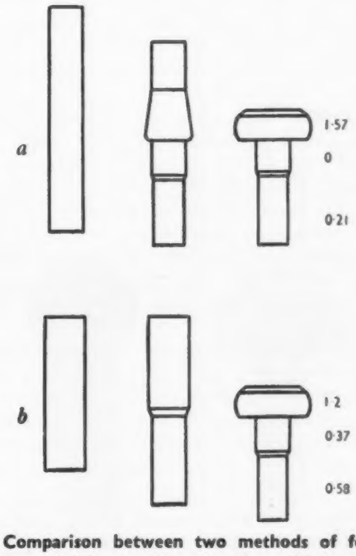

Fig. 11. Comparison between two methods of forging the same product: (a) by two-blow heading; (b) by progressive heading (the figures refer to the degree of deformation).

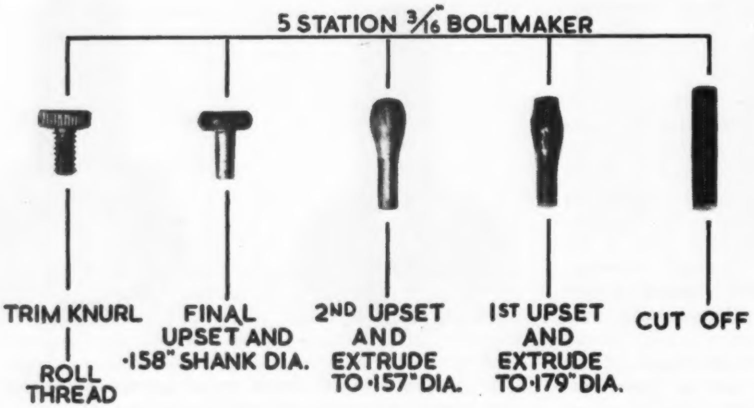

Fig. 12. An example of the use of a transfer header to obtain progressive reductions in a series of dies and, at the same time, to upset progressively a relatively small amount of material for the head. The example shows the use of the final punch station as a trimming operation.

punch is allowed to pull the blank from the die and a specially cammed ejector at the back of the punch ejects the forged blank from the punch.

The maximum cut-off length is determined by the design of the header required for forging a particular component; in practice, the cut-off length is a compromise between the head form required and the final overall length of the product.

extrusion

Extrusion is the term used when the wire diameter is reduced by forcing the wire through a conically formed extrusion ring contained within specially designed heading dies. It is an operation which can be carried out while the slug is being forged or it can be carried out as a secondary operation, for example, by the use of a reheader.

The conditions are ideal because compressive forces are applied so that compressive stresses result along two axes and, provided that the slug is guided, buckling is obviated. The limit of extrusion is determined largely by the maximum stress which can be sustained by the tools.

An extrusion die is designed to have a bore diameter slightly larger than the slug or blank diameter and this diameter bore extends as far into the die as this larger diameter is required. A conical form connects this larger diameter to an extruding ring which has a diameter equal to the reduced shank diameter required, and the ring extends into the die by about .030 in. Beyond this ring extends a hole whose diameter is greater than that of the ring by about .002 in.

There are limitations to the use of extrusion as a means of obtaining a very accurate shank diameter (which is usually required for thread rolling) and as a means of saving material and time (compared with other methods such as turning and grinding to obtain a similar reduction). These limitations are that:—

(a) it is necessary with normal cold forging machines, for the extrusion die to have a conical form leading to the extruding ring. The cone angle will usually be about 30° included but variations of this angle are possible (usually between 20° and 45°). Hence, the profile of the component will repeat the conical form of the die shape, but this cone can be removed by the use of secondary operations if a square shoulder is essential;

(b) the degree of deformation by extrusion in one die has a maximum value of about 30% reduction in area, based on the area of the original blank entering the die. Greater reductions are possible by repeating the extrusion process in another die, i.e. on a reheader or by the use of a transfer header (see Fig. 12);

(c) due to the high loads imposed on the extruding ring, tool lives tend to be relatively low when compared to the life of a plain hole die. However, when large numbers of components are concerned, the use of carbide tooling maintains a low unit cost;

(d) not all materials are capable of being extruded successfully, as extrusion depends on ductility and the ability of the tool design to provide adequate support if the material is soft. By suitable techniques it is possible to extrude soft copper and aluminium alloys, etc.;

(e) there tends to be a limit on the length of the extruded portion, determined on one hand by the stroke of the header and on the other hand by any tendency for the extruded shank to be bent on ejection. Bent extruded shanks are not a common feature but they can occur, more especially on long lengths. It is considered that tool accuracy is the essential requirement and tool standards must be of the highest order. Special tooling can be used when the extruded length is longer than the plain part length, e.g. by using deeper extrusion rings or by using double extrusion rings spaced apart to give the maximum support during ejection.

It is interesting to note that, because wire for extrusion is often phosphate-coated to reduce the frictional forces involved, a definite surface layer is formed during extrusion. This surface is a work-hardened surface but it will have a very small depth of roughness, which can be

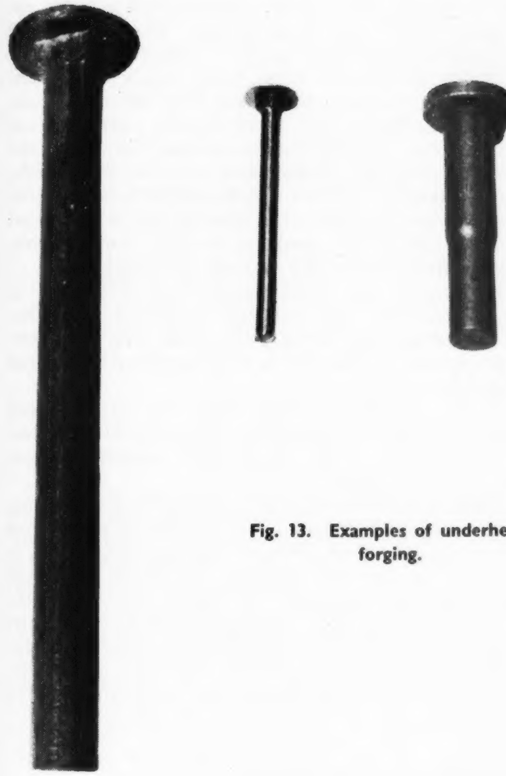

Fig. 13. Examples of underhead forging.

as low as one micro-inch surface finish, and compares very favourably with the finish obtained with other forms of reduction.

underhead forging

It has been mentioned previously that extrusion and upsetting of the head can be carried out simultaneously. It is also possible to increase the diameter of the shank immediately underneath the head.

This enlargement can be round, square or even non-concentric. However, the volume of this additional shoulder must be included in the length of wire required for upsetting when calculating the upset ratio.

If the underhead forging is to be a square, it must be realised that absolutely sharp corners cannot be achieved by direct forging. The corners of the square will always be slightly rounded (see Fig. 13). This effect can be minimised by forging on a split die header and arranging for two diametrically opposed corners to coincide with the divisions of the die. Other limitations are that the length of the square should not exceed about 60% of the maximum wire diameter for the machine, and that 1° per side draft should be expected.

Forged ribbing is sometimes used as an alternative to a square neck or to lugs where the application is one where resistance to turning is required. Forged ribbing tends to be less costly than knurled ribs formed in a secondary operation. However, the amount of ribbing is limited to about one wire diameter in length and the degree of "filling out" is dependent upon the head shape and the raw material in use. The cross-section of the ribbing should be such that the form is self-relieving.

An underhead form can also be obtained by projecting the face of the die (see Fig. 14).

radii

Square inside corners on load-carrying components are areas of stress concentrations. Round corners allow for a smooth transfer of stresses and fortunately the formation of a radius is a characteristic of the cold forging process. If a sharp corner is necessary, it can be obtained by means of reheading or another secondary operation (see Fig. 15). If the shank is to be stepped, it is more convenient to design in a taper than at the step.

Hence rounded corners are desirable for two reasons—they tend to improve the strength of the component and their inclusion reduces the cost of the component. Radii should be as large as is practicable and, as a general rule, a radius of 5% of the wire diameter is quite possible to forge.

points

It is usually impossible to obtain a complete cone point by forging—although it can be obtained by other methods, for example, pinch pointing and special pointing attachments. The shape of a forged point is that of a truncated cone, due to the essential requirement of a flat end for ejection purposes.

The limiting factors to the forging of a forged point are that:—

(a) only solid die machines can be used;

(b) in the case of single die machines, the shank must be a plain diameter, i.e. two extrusions cannot be performed within the single die;

(c) the reduction in area at the point should not exceed 30%, and the cone angle not more than about 45° included;

(d) as the diameter of the die plunger (i.e. the ejector) will be the size of the small end of the point, the strength of the plunger is somewhat reduced and there will be a limit to the maximum length of material which can be ejected

Fig. 14. Examples of underhead forging by using specially designed heading dies with projecting top surfaces.

Fig. 15 (from left to right). (a) a well-defined hexagon under the head was required. This blank was forged as a cheese, the blank was then trimmed to a hexagon and, finally, reheaded to obtain the thin cheese washer; (b) sharp corners were required underneath the head and at the change of section and, in addition, a straight-sided shank end was desired. All these features were obtained by using the transfer header method. The uneven end shown at the bottom of the shank is typical of extruded ends, i.e., the result of differential extrusion, which is hard to control; (c) with this example sharp corners were obtained by normal two-blow solid die methods but at the expense of die life.

from the die. This is a function of the length/diameter ratio for the plunger and the frictional forces involved. For example, only about 8 diameters of wire can be ejected for shank diameters below .100 in.—provided that the minimum diameter of the small end of the point is not less than .060 in.

A forged point can be forged on an extruded shank by indirect means, i.e. by the transfer header method. In this case, a point is forged on the slug in the first station die and a register of this point can be retained throughout each of the subsequent operations including extrusion.

tools for cold forging

It should be noted that tools are never inelastic at the point of forging — no matter how solidly they are made; increasing the size of the tool will not defeat the tendency to be elastic. In general, the ultimate property of cold forge tooling is about 90 tons tensile, with an elongation of 15% - 20% when designed for standard tool pockets.

Tooling deflections are difficult to measure quantitatively but it is reasonable to expect a deflection of up to .0015 in. on a $\frac{3}{16}$ in. machine and a deflection of up to .003 in. on a $\frac{1}{2}$ in. machine. These deflections are at their maximum at the mouth of the tool.

Inserts are usually made from $12\frac{1}{2}\%$ high speed steel. This is a deep hardening steel which contains complex carbides and it tends to give a greater elongation— hence a tendency to oversize blanks —than the 12/2 chrome carbon steel used in the U.S.A., i.e., we tend to use a material which is more wear resistant and tougher. The inserts are heat treated to about 56/58 Rc., and are designed for an interference fit of up to .008 in. with the mating case.

Insert cases are usually made from EN.39B (4% Ni. Cr.) and are case hardened to give about 60 Rc. on the surface and 40 Rc. in the core. The inner bore is phosphated if the case is to be used for high speed steel inserts.

Finish punches are made from 1% carbon steels and heat treated to 56/58 Rc. Die and punch ejectors are made from high speed steels containing from $12\frac{1}{2}\%$ - 18% tungsten.

Carbide inserts are made from material containing from 12% - 18% cobalt. The selection of the correct cobalt quantity depends upon the application, but, as a guide it is fair to state that " the lower the cobalt the harder the material, the higher the cobalt the tougher the material ". Carbide tools are inherently weak in tension and it is therefore essential to support such tooling with interference fits of up to .008 in. Press-stress can be obtained either by shrinking or by forced fits.

materials for cold forging

It is fair to state that numerous materials, which hitherto could only be used as bar products material, can now be cold forged — provided that proper care has been exercised in the design of the tools and in the selection of the forging method. The cold forging process, however, sets certain limits on the material to be forged if the cycle of operations is to be continuous and, at the same time, successful. The choice of material for cold forging is governed by the often conflicting interests of ease of forming and the required properties of the finished component or finishing processes. The effects of lead and sulphur are disastrous to cold forged materials.

It will be seen, therefore, that the ideal circumstances for forging exist when the choice of material is left to the manufacturer. It is sufficient for the designer to specify the physical and mechanical properties that he requires from the finished component; any additional information on the application of the component would be of great use in the selection of the manufacturing route. It is often more advantageous to obtain the desired properties from work hardening than from heat treatment.

The most commonly used material is carbon steel for it has the merit of being low in cost, and it is easily and cheaply worked. The lower the carbon content the greater the ductility and the lower the load required to deform the material (see Fig. 16). Increased carbon content will allow a stronger final product with heat treatment.

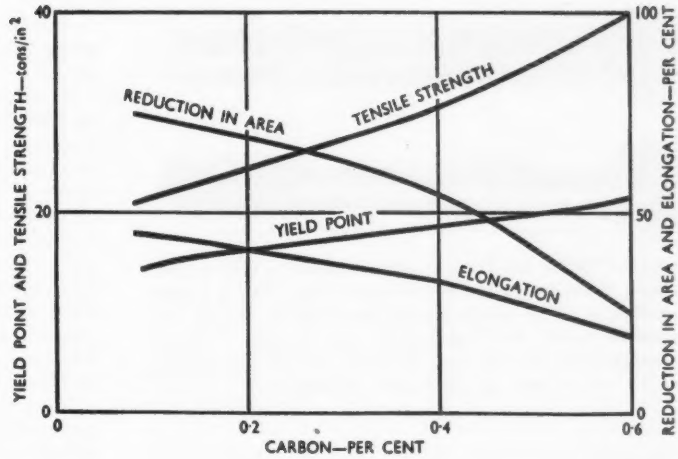

Fig. 16. The influence of carbon content on the physical properties of cold forging steels as hot rolled.

The basic principle in utilising low carbon steel is one of increasing the strength of the material by cold working and, hence, obtaining a fair strength from a very cheap material, but there are limits to the total amount of cold work practicable.

Cold heading wire is produced by cold drawing hot-rolled rod. The effect of cold drawing on tensile strength, reduction in area and elongation can be shown (see Fig. 17). As reduction is increased, the strength of the material is increased but the ductility is reduced. The amount of prior work hardening by cold drawing is limited in order that the ductility of the material is not reduced to a degree whereby the required upset cannot be attained.

If the wire is drawn immediately before cold forging, the wire tends to have a lower yield point. However, this activity necessitates the use of power-operated feed rolls and the consumption of a considerable amount of space in front of each forging machine. On the other hand it does mean that the wire sizes held in stock can be rationalised and the number of different sizes reduced considerably.

Severely worked parts require heat treatment to restore some degree of ductility. This may be a low temperature stress relieving treatment, a normalising or a full annealing treatment or a full harden and temper.

For normalising and annealing this involves some loss in strength, depending on the temperature of the particular treatment involved. While the necessity for a process anneal depends on the severity of the forming operation, a given shaped part may or may not require a process anneal, depending on the method used for the forming. However, it is worth noting that it is possible to manufacture, from low carbon steel, bolts with certain head forms with a tensile strength of 45 tons per square inch which may be used safely without process annealing.

Where a cold forging operation is severe, a rimmed steel is frequently used. The outer skin of this type is very ductile because of its low carbon content, so reducing the risk of surface cracks being formed in the product. The use of this type of material is limited to carbon contents not exceeding about 0.2% carbon.

The presence of sulphur and phosphorus as impurities in the steel has an adverse effect on the ability of the steel to be cold worked. Sulphur occurs as sulphides and hence reduces the available ductility of the steel, but the effect is unimportant below 0.05%. On the other hand high sulphur free-cutting

Fig. 17. The effect of cold drawing on the tensile properties of 0.3% carbon steel.

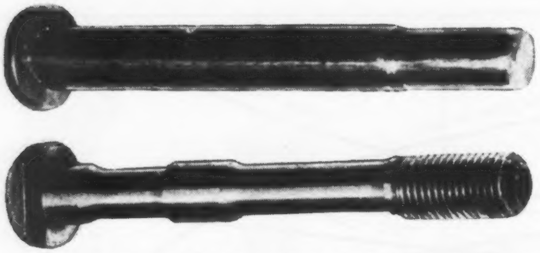

Fig. 18. Typical connecting rod bolt obtained by cold forging, shown in the forged and in the finished state. This is a good example of a high quality product obtainable by forging. i.e., optimum grain flow conditions and minimum material wastage. The eccentric head form was obtained by forging and by subsequent trimming.

steels (e.g., EN 1 A) are not suitable for cold forging due to their tendency to split.

The nature of the steel-making process may have special advantages to offer as distinct from the straight analysis. For example, acid Bessemer steel is well known for its better machining characteristics compared with a similar composition produced by the open hearth process.

In the case where the forging operation increases the diameter of the blank, considerable circumferential strain is involved. Wire of good surface quality must therefore be used if defects are to be avoided. The presence of seams and laps in the surface of the wire have to be avoided and special precautions (such as ingot dressing or heavy scaling during or after the rod rolling stage) are sometimes taken to provide wire of superior surface quality.

For the manufacture of components which require a higher strength than can be obtained from cold worked low carbon steel, a medium carbon or alloy steel is used—the required properties being obtained by heat treatment. The use of medium carbon steels is limited to sections which can be through-hardened by oil quenching. To produce the optimum physical properties it is necessary to harden throughout the section.

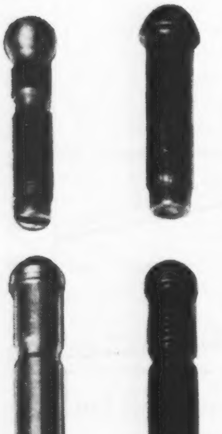

Fig. 19. Example of a design change resulting from direct discussions between the product designer and the manufacturer. The blank (top left) is the original ball head form. The blank (top right) shows the modified hemi-spherical head form which could be obtained far less expensively with the redesigned tools and still fully satisfied the needs of the application.

In most cases cold heading wire is prepared with a coating of lime and dry drawn using a metallic soap as a lubricant. The thickness of the coat can be controlled. For heavy extrusions particularly, a heavy lubricant coat is essential if a satisfactory die life is to be attained.

Medium carbon and low alloy steel wires are improved for cold forging if the intermediate wire drawing heat treatment develops a favourable spheroidised carbide microstructure. Wire with this structure will forge more easily than any other structure. The final wire condition will therefore be spheroidised and then soft or bright drawn.

General steels for cold work, for example, EN2, are listed in B.S. 970; B.S. 3 111 covers materials for cold-forged, high-tensile work.

Typical low carbon steels :

Carbon	0.15/.20	.30/.40	0.1/0.15
Manganese	0.6/0.8	0.8/0.9	0.4/0.55
Sulphur	.05 max.	.04 max.	.05 max.
Phosphorus	.04 max.	.04 max.	.05 max.
Silicon	—	0.1	.015 max

(Medium carbon steels: 0.3/0.45 carbon plus nickel, chromium, vanadium, boron, molybdenum, etc.)

The use of cold forging is in no way limited to ferrous material. Copper, silver and certain brasses and bronzes can all readily be forged. For upsets in brass, the copper content of the brass should be at least 62% and impurities should be controlled, particularly lead and iron.

Stainless steels are well known for their higher work hardening characteristics. Over the past few years, considerable knowledge has been gained in forging these steels and successful forging techniques have been developed for both ferritic (plain chromium) and austenitic 18/8 type stainless steels. The nickel content can be increased so as to reduce the rate of work hardening, e.g. EN 58 E (SF 920).

Typical stainless steels :

	SF 920 *EN 58E* *	*SAE 305*	*XA 4* *Carpenter 10*
Carbon	.08 max.	.06 max.	.03 max.
Manganese	2.0 max.	2.0 max.	2.0 max.
Sulphur	.045 max.	.045 max.	.045 max.
Phosphorus	.045 max.	.045 max.	.045 max.
Silicon	.2/.1	.2/.1	.2/.1
Nickel	8/10	11/13	17/19
Chromium	17/20	17/20	15/17

* Non-magnetic in annealed state

lubrication

There is no doubt now that the key to successful forging lies within the field of lubrication. Practical experience indicates that forging conditions vary from hydro-dynamic to boundary layer conditions.

Several methods of lubrication are in current use :

(a) the stearates, for example sodium stearate;

(b) graphite and moly-disulphide;

(c) the palmitates, for example aluminium palmitate, a hydrogenised dry soap (a vegetable palm oil as opposed to a mineral oil);
(d) extreme pressure lubricants, i.e., mineral oils with sulphurised or chlorinated fatty oils or waxes.

For forging stainless steel the current solution still appears to be an adequately applied copper coat.

Because of the demands of mass production forging (machines must run continuously after setting up) it is essential that, whatever lubricant is used, the dies and punches are kept clean, i.e., checking any tendency for the tools to be clogged up.

design drawing and specification

dimensions

It is most convenient if the largest diameter of upset is used as the base line, as this upset is frequently associated with the face of the die, i.e. the die line.

It is of great advantage to the manufacturer if one dimension can be left "open". It will be seen that, with wire tolerances of .002 in., tool-making tolerances of .0005 in. and the dependence upon machine setting to achieve the final desired component shape, it is necessary to have one part of the component free from restrictions in order to accommodate any volumetric variations.

The important dimensions should always be clearly defined.

tolerances

A graph of price plotted in relation to tolerances indicates that price rises considerably as the tolerances are reduced. In addition, it is always good practice to specify as wide tolerances as the application will permit, for the obvious reasons that tool lives are considerably increased and thus longer production runs can be obtained.

It is extremely difficult to lay down specific rules on tolerances due to factors such as material forgeability, component design and so on. However, the following tolerances are given as a guide to the possibilities of the cold-forging process:

Head Tolerances:

Nominal shank diameter	Tolerance range		
	Height	dia. plain head	dia. recess head*
Up to $\frac{3}{16}$ in.	.008 in.	.010 in.	.012 in.
$\frac{3}{16}$ in. to $\frac{5}{16}$ in.	.009 in.	.012 in.	.018 in.
$\frac{3}{8}$ in. to $\frac{1}{2}$ in.	.010 in.	.015 in.	.025 in.

*If the head form contains any form of recessing, for example, hexagon socket, material does not flow evenly to the periphery of the head form. The amount of irregularity will vary depending upon the recess and the head shape.

Shank Tolerances:

Nom. Shank dia.	Tolerance range
Up to $\frac{3}{16}$ in.	.002 in.
$\frac{1}{4}$ in.	.0025 in.
$\frac{5}{16}$ in. & $\frac{3}{8}$ in.	.003 in.
$\frac{1}{2}$ in.	.0035 in.

It is with shank tolerances that the greatest need occurs for as wide a tolerance as is possible. Obviously, the wide tolerance is the most economical to meet. In the cold forging process, there is always a tendency for the material in the shank to forge up slightly at a position immediately under the head (due to the plastic deformation of the tool and partly to "breathing" of the tool assembly) and, in the case of non-extruding dies, at the extreme end of the shank where contact with the ejector is made. A closer tolerance than .002 in. can be held over the range, but special tooling may be required especially if the size and shape of the part is abnormal. Close shank tolerances generally lead to a secondary finishing operation, but they are applicable where cost is of lesser importance than the close adherence to specified dimensions.

Length Tolerances:

Length	Tolerance range
Up to 1 in.	.010 in.
1 in. to 3 in.	.060 in.
3 in. to 6 in.	.080 in.

In this context, length would be defined as the distance between the extreme end of the longest section to the nearer largest diameter of the upset portion, i.e. that part of the component held in the die.

With this dimension also the elastic deformation of tools has an effect. As the size of the wire and the tensile of the wire increases, the effect tends to be additive.

All tolerances should be applied according to British Standard conventions.

concentricity

In cold forging concentricity is understood to be the variance of one diameter to another relative to a common axis. As the punch and the die are separately mounted, the achievable concentricities are dependent on the clearances of the punch slides, the accuracy of the tool making, the accuracy of setting up and the actual design of the component.

Concentricities are best specified as total indicator readings. Acceptable T.I.R.'s are in the region of about .005 in. at the small end of the scale and increase to about .020 in. for large diameter heads and shanks.

eccentricities

Deliberately designed eccentricities should be avoided wherever possible. It should be noted that

an easy way to avoid an eccentric form is to forge a concentric shape and to trim the eccentric form in a subsequent operation. Eccentricities should be related to a centre line of the component and important features, if any, should be carefully noted.

points

Unless a particular type of point is essential, it is convenient if the point detail is omitted. The drawing should indicate that a point is desired and thus enable the manufacturer to choose the best point form with regard to the manufacturing route.

head marking

It is not often realised that identification marks are readily forged on to the top of the component. The marks can be either indented or forged so that they stand proud of the main surface — the latter method is preferable. The marks should be arranged around the outer edge of the top face rather than across the middle if an even definition is required.

Protrusions or indentations can also be produced on the underside of the head, e.g., projection welding bosses are forged very readily merely by indenting the surface of the die at the manufacturing stage.

component application

It is of considerable benefit if essential surfaces and edges are noted. As sharp corners are not produced readily in the cold forging process, drawings should indicate exactly where sharp corners are essential.

A knowledge of the actual application of the component materially assists the manufacture of the component (see Figs. 18 and 19).

If the forged component is to be re-fed into secondary operation machines, it is often necessary to insist that some form of head is forged in order to facilitate re-feeding down feed rails — the head can be removed as one of the final operations.

final considerations

Reduction in the amount of waste by forming to a shape, or to near finished dimensions, components otherwise made from the bar, not only reduces the quantity of material converted to near worthless swarf, but also reduces the machining costs which go with it. Additionally, if the component is one of steel, cold forming can provide as a result of cold working improved physical properties from a lower grade of steel. From the point of view of cold forging, limiting the amount of material to be upset to the minimum volume which will meet the requirements of the component greatly increases the ease with which the component can be forged.

Ideally, if the benefits of material economy (and thus of cost reduction) are to be maximised, the designer must concern himself with some of the less obvious factors—for example, accurate stress work should be carried out to ensure that the functional needs plus the appropriate safety factor, but no more, are covered in the design and specifications. Insistence on unnecessarily fine tolerances and designing abnormal forms where standard ones are completely adequate can only result in minimising the benefits.

Thus, it is sufficient to stress the need for more collaboration between the product designer and the cold forging industry; such co-operative efforts are bound to yield beneficial results.

"AUTOMATION — MEN AND MONEY"

The first British Conference on the social and economic effects of automation, sponsored by eight major institutions (including The Institution of Production Engineers) under the aegis of the British Conference on Automation and Computation, is to be held at Harrogate from 27th - 30th June next, and will be opened by The Rt. Hon. Viscount Hailsham, Q.C., Lord President of the Council and Minister for Science.

Details of the programme, together with an application form for registration, were circulated with the March issue of *The Production Engineer.*

Mr. A. L. Stuchbery, M.I.Prod.E., Vice-Chairman of Council, Institution of Production Engineers, will present a Paper on **"Physical Requirements of Automation",** in Session D1 of the Conference, and another Institution member, **Mr. A. A. Jacobsen,** Works Manager of Roneo Ltd., Norwich, is to present a Case Study, in Session F1, on **"Economic Aspects—Internal to the Firm".**

The speaker at the Final Plenary Session will be the Chairman of B.C.A.C., **Sir Walter Puckey,** M.I.Prod.E., Past President of the Institution.

A capacity attendance is anticipated for this important Conference, and Institution members who have not already done so are strongly advised to make their applications without delay. All correspondence should be addressed to: **Mrs. J. Hodson, Conference Secretary, The British Institute of Management, 80 Fetter Lane, London, E.C.4.**

REPORT OF THE MEETING OF COUNCIL

Thursday, 26th January, 1961

THE third Council Meeting of the 1960 - 1961 Session was held at the Headquarters of the Institution, at 10 Chesterfield Street, Mayfair, London, W.1, on Thursday, 26th January, 1961. The Chairman (Mr. R. H. S. Turner) presided over an attendance of 26 members.

Before proceeding with the business of the meeting, the Chairman extended a particularly cordial welcome to the Vice-President, Mr. H. Burke, on his return after undergoing an operation. A special welcome was also extended to Mr. E. W. Huggins, Chairman of the Northern Ireland Region, whose presence, as far as could be recollected, marked the first occasion on which a representative from Northern Ireland had been present at a Council Meeting for many years.

Also welcomed, as visitors, were: Mr. J. R. Jones, Chairman of the Liverpool Graduate Section; Mr. D. R. Stockdale, Chairman of the Loughborough College Students Section; and Mr. G. R. Wimpenny, Hon. Secretary of the Doncaster Section.

Nomination of President and Vice-President

The President (Mr. G. Ronald Pryor) said it gave him the greatest possible pleasure to nominate Mr. Harold Burke for the Presidency for the year 1961 - 1962. For many years Mr. Burke had worked unceasingly for the Institution in the Regions and Sections, and also served as Vice-Chairman and subsequently as Chairman of Council.

Although the Presidency was the highest honour that the Institution could confer on any member, Mr. Burke would also go down to posterity as the author of the Burke Report, which had had a very great influence on the development of the Institution.

In reply, Mr. Burke said that this was a momentous day for him. The Presidency was indeed the highest honour that could be offered to a member, and that was how he regarded it. He felt very humble at being so honoured and could do no more than assure the Council that he would do his very best to uphold the high traditions of the office, and the very fine example which had been set by a long list of illustrious Presidents of the Institution.

It was traditional, Mr. Burke continued, that the Vice-President should nominate his successor, and he therefore had pleasure in submitting the name of Mr. R. Ratcliffe as Vice-President for 1961 - 1962. Mr. Ratcliffe was not only well-known to the membership, but perhaps even better known as the holder of the very important appointment of Controller of the Royal Ordnance Factories. He was a man of great influence industrially, and had done a great deal of work for the Institution, notably as Chairman of the Education Committee. In Mr. Ratcliffe, the Institution would have a leader, in due course, of whom members could be very proud.

Future Institution Policy

The Chairman reminded the Council that at a previous meeting he had been empowered to empanel a Committee to consider the future policy of the Institution. After consultation with colleagues he had reached the conclusion that the right and proper Committee to be empanelled for this purpose was in fact the full Finance and General Purposes Committee.

This Special Committee had so far had two meetings and had considered three very important matters. The first was the question of the publication of research reports; the second concerned what the Institution could do regarding technicians; and the third was to consider all aspects of membership of the Institution.

With regard to the first item, it was now recommended to the Council that the Institution should publish Production Engineering Research Reports as a regular feature, possibly as a quarterly publication. It had been established by the Special Committee that there was a need for such a publication, apart from the Institution's Journal, and that there was sufficient material available for publication. It had been agreed to appoint an Honorary Editor-in-Chief who would gather round him an international board to collect material, and that the administrative side of the publication should be dealt with by the Editorial Committee.

The Committee were pleased to report that Professor N. A. Dudley, of the University of Birmingham, had undertaken to act as Editor-in-Chief, and he had assured the Special Committee that he could surround himself with an international board of very high standing.

The recommendation was adopted unanimously.

No conclusions had yet been reached regarding the other matters under discussion.

Finance

The Council adopted the recommendation of the Finance and General Purposes Committee that the

Institution Seal be affixed to share transfer documents referring to the purchase of £5,000 1971 5% stock.

Mr. Cecil F. Hammond, M.I.Prod.E.

It was reported that Headquarters had been recently honoured by a visit from Mr. Hammond, who had taken a very active part in Institution affairs in its early days, and was in fact Chairman at the inaugural meeting on 26th February, 1921.

In recognition of his past service, the Finance and General Purposes Committee had agreed that Mr. Hammond be made a free life member.

Appointment of New Technical Officer

The Council were advised that applications were now being considered for the vacancy caused by Mr. I. B. King's recent return to industry.

Secretary's Report

The Chairman drew attention to the fact that the Secretary's Report took a rather different form from that normally presented. After 10 years in the appointment, Mr. Woodford had thought it appropriate to make an historical review of the Institution's activities during his period as Secretary.

It was agreed that this formed a most interesting record, and it was recommended that the Report be published in the Journal (see pages 233 - 236).

Mr. C. Sumner, referring to the Secretary's comments in the report regarding the part played by the Southampton Section in organising the Aircraft Production Conference, asked Council to record special appreciation of the contribution made in this regard by Mr. Joe Turner, a Past Chairman of the Section. In agreeing to this, the Chairman added that it was appropriate at this time to express to the Southampton Section in general sincere thanks for the wonderful work which they had done. The Aircraft Conference would not have come to realisation unless the Section had taken the lead, and they were to be congratulated on their achievements.

Education

It was reported by the Education Officer (Mr. F. W. Cooper) that following the recommendations made in the Turner Report, it had been decided that the Education Committee should in future meet quarterly as a Policy Committee, and that a Sub-Committee should meet during the other two months. The terms of reference of the Sub-Committee were :

(a) to re-examine the academic standard of the A.M. examination, with particular reference to professional status, mathematical content, its effect on H.N.C. in production engineering, recommended text books;

(b) to examine the present standards of H.N.C. in production engineering;

(c) to consider the status of technicians.

Membership

The Council approved a number of applications for membership and transfer, details of which appear on pages 300 - 301.

It was reported that the Practical Training Report was now in the hands of the printer.

The Journal

It was reported by the Editorial Committee that the rising production costs of the Journal, largely influenced by the sustained high increase in membership coupled with an increase in the cost of paper, made it imperative to find some means of increasing the revenue. It had therefore been agreed that the advertising rates for the Journal should be increased by 25% for all new advertisers on 1st April, 1961, and for all renewals after that date. This action was in line with increases being made by other publications, but even so, the page/circulation cost to advertisers in the Journal was still below that of other technical Journals.

The sale of advertising space had been maintained during the quarter and the Committee wished to record appreciation, on the Institution's behalf, to all members and affiliated organisations for their support in this regard.

Institution Papers

It was reported by the Papers Committee that two Named Papers had been presented during the quarter.

The first was The 1960 Sir Alfred Herbert Paper, "The Doctor in Industry", given at The Royal Institution, on 10th November, by Professor R. E. Lane, of the Nuffield Department of Occupational Health, University of Manchester. The Paper was followed by a good discussion on a subject of considerable importance to production engineers.

The second Paper was the 1961 Lord Sempill Paper, which was presented at The Royal Aeronautical Society on 25th January, by Sir Percy Hunting, lately Chairman of the Hunting Group of Companies. The subject, "The World's Future Transport Requirements", attracted a capacity attendance, including a number of leading personalities from the aircraft world, some of whom took part in the discussion. The meeting had been well noticed by the national and technical press.

Research

The following reports were received from the Research and Technical Committee :

Materials Handling Group

Following visits by representatives of the Group Committee, new Materials Handling Sections had been formed in Cardiff and in Swansea. The Materials Handling Section in Bristol had also been reactivated.

The Study Group arranged by the London Materials Handling Section, which ran for six weeks at the Institution's Headquarters, was well attended and was very successful. Arrangements were well advanced for the lecture in March on "Birmingham in 1970" promoted by the Birmingham Materials Handling Section.

The National Joint Committee on Materials Handling was in touch with B.S.I. concerning the need for a glossary of materials handling terms, and participation continued in the Study Groups set up by the National Joint Committee.

Discusssions were continuing on the programme for the proposed Materials Handling Conference to be held later this year.

Computer and Production Control

It was expected that the report would be published in a few months' time.

Control of Quality

The series of articles prepared by the Sub-Committee was now appearing in the Journal. The Sub-Committee were at present drafting a booklet explaining quality control in very simple terms. It was felt that there was a great need for a publication of this type, which could be distributed to factory staff.

The Sub-Committee continued its liaison with the British Productivity Council Quality Control Advisory Committee.

Co-ordination of Production Management Techniques

The final draft of the report was now being collated.

Standardisation

Arising from the discussion on the need for a greater knowledge of British Standards and International Recommendations in the Institution's examination syllabus, the Sub-Committee on International Standardisation felt there was a lack of textbooks for students on the basic principles of standards, and this question was being explored. It had also been decided to keep under review the inch/metric problem.

Arrangements were virtually complete for the Annual Standards Conference organised by the Joint I.Prod.E./B.S.I. Standing Advisory Committee on the use of Standards in Industry, which is to take place in London on 9th and 10th May, 1961.

The Committee continued active liaison with the B.S.I., B.P.C., and the British National Committee for Non-Destructive Testing. The latter body had invited the Institution to organise a symposium on Standards and Standardisation in Non-Destructive Testing, in London, in 1962. The invitation had been accepted in principle.

The Library

It was reported that as a result of an announcement in the Journal Supplement, several members of the Institution and firms had offered to co-operate in the production of the history of the manufacture of the small electric motor. Progress had been made in the preliminary investigations.

The Library had been very busy during the quarter. There were about 15% more enquiries than during the corresponding period last year.

Region and Section Reports

The Council received a number of Region and Section Reports, and there was considerable discussion on various matters raised in the Reports, several of which were referred to the appropriate Standing Committees for further action.

Liaison with Overseas Sections

The Secretary, in the absence of the Vice-Chairman of Council (Mr. A. L. Stuchbery) reported that the first Chairman of the newly-formed Section in Bangalore was Mr. R. L. Kapoor, an old member of the Institution.

A long and interesting letter had been received from Mr. Brownlee, of South Africa, in connection with examination standards. A letter had also been received from Mr. Jack Merkine, Corresponding Member in the Middle East, in which he had made some valuable suggestions.

Honours

The Council were pleased to record the inclusion in the New Year's Honours list of the following members:

C.B.E.

Mr. J. R. Pheazey, M.I.Prod.E.

M.B.E.

Mr. F. Baker, M.I.Prod.E.;
Mr. C. J. Tyrrell, M.I.Prod.E.

Obituary

The deaths of the following members were recorded with deep regret:

Member

Sir Cecil Weir, K.C.M.G., K.B.E., D.L.M.C., Past President.

Associate Members

E. T. W. Barnes; T. H. Weaver.

The Chairman referred particularly to the death of Sir Cecil Weir which, he said, was a sad loss not only to the Institution but to the country. He would always be remembered with great affection by those who had known him or had come into contact with him.

Next Meeting

It was agreed that the next meeting of the Council should take place on Thursday, 27th April, 1961, at 11 a.m., at the Headquarters of the Institution, 10 Chesterfield Street, Mayfair, London, W.1.

COUNCIL ELECTIONS

A PRELIMINARY NOTICE APPEARS ON

PAGE 236.

ELECTIONS AND TRANSFERS

26th January, 1961

BIRMINGHAM SECTION
As Graduates
S. V. Vaughan; J. F. Baugh; J. G. Warren; J. A. Williams; B. T. Wilkinson; R. Sale; K. W. Cook; D. J. Sutton; D. G. Garrett; M. Thomas; B. L. Roberts; R. J. Padfield; D. A. Phillips; T. F. Parr.
As Students
D. W. Train; P. R. Dagnall; A. G. Evans; P. W. Cross; A. Virmani; P. J. Reynolds; D. A. Hayward; G. Massey; B. J. Black; J. D. Incledon; K. J. Phillips.
Transfers
From Associate Members to Members
J. Longden; E. A. O. Smith; W. H. Telling.
From Graduates to Associate Members
P. Scott; G. E. Hayes, H. E. Furness.
From Students to Graduates
J. D. Clutton; M. J. G. Billingham; S. Chakravarty.

BOMBAY SECTION
As Members
A. R. Iyer; S. L. Kirloskar.
As Associate
P. B. Prebhu.
As Graduates
P. Singh; W. S. Venkateswaran.
As Students
S. P. Paul; S. Sharma; R. J. Almeida.
Transfer
From Associate Member to Member
W. P. Karnik.

CALCUTTA SECTION
As Graduate
M. L. Khanna.
As Student
R. K. Gupta.
Transfers
From Graduates to Associate Members
A. K. Bhattacharya; A. K. Dutt.

CANADA SECTION
As Graduates
J. Kilpatrick; M. Parkes.

CARDIFF SECTION
As Graduates
B. Hitchings; B. G. Meredith; L. G. Gull; K. Collins; B. J. V. Conway; T. E. O'Neil; D. M. L. Jones.
As Students
C. T. Harris; B. Wilton; D. G. Jones; M. G. Osland; G. H. Thorne; I. Davies; G. C. Morgan; T. W. Davies.
Transfers
From Students to Graduates
H. B. Pearson; D. J. Carpenter; C. Isaac; L. H. Belcher; K. Wylie; D. O. Phillips; D. J. Phillips.

CORNWALL SECTION
As Student
M. J. Chambers.
Transfer
From Graduate to Associate Member
R. H. Lowres.

COVENTRY SECTION
As Graduates
P. M. Marsh; A. W. Robbins; T. Bolton; J. W. Iveson; S. M. L. Hui; N. J. Brown; B. Lanchbury; J. A. Cawfield; J. Castle; J. M. Senior; O. E. Roberts.
As Students
W. D. Vasper; B. S. Bevan; A. H. Leech; R. W. James; T. A. Roberts; A. N. Howe; W. W. Y. Huang.
Transfers
From Graduate to Associate Member
D. Baxter.
From Students to Graduates
A. J. Wade; P. A. Thomas; D. Payne; W. R. Gregory; D. J. Knight; A. Dennis; R. M. J. Whitehead; R. L. Scowen.

DERBY SECTION
As Graduates
A. P. Heap; M. Petch; A. R. Wheatcroft; W. M. Jackson; T. Farnsworth.
As Students
J. Flint; J. P. McMahon.
Transfers
From Associate Member to Member
G. F. G. Hinings.
From Student to Graduate
D. W. Ryall.

DONCASTER SECTION
Transfer
From Graduate to Associate Member
J. H. Beddard

DUNDEE SECTION
As Associate Member
G. W. Wood.
As Graduates
G. L. Millar; J. Comrie; W. Black.

EDINBURGH SECTION
As Student
D. M. Ross.
Transfer
From Associate Member to Member
C. Phillips.

GLASGOW SECTION
As Graduates
J. Robertson; J. D. Borland; W. Hawkes; G. P. T. Anderson; I. Sutherland; M. C. Quinn; L. J. Clemie; W. T. Lees; J. W. H. Tyler.
As Students
T. H. Nugent; G. Bell; J. Martin; T. Jaap; T. B. Holden; W. S. Denham.
Transfers
From Associate Member to Member
D. R. Snowden.
From Graduate to Associate Member
W. A. Leach.
From Students to Graduates
A. B. L. Wu; J. S. Maxwell; J. Mitchell; G. M. Hoskins

GLOUCESTER SECTION
As Graduates
T. E. Lush; C. M. R. Palmer.
Transfers
From Graduates to Associate Members
G. H. Hines; S. H. Kite; H. Hindle.
From Student to Graduate
D. Rowles.

HALIFAX & HUDDERSFIELD SECTION
Transfer
From Student to Graduate
G. R. Blackburn.

IPSWICH SECTION
As Graduate
J. Henfrey.
Transfer
From Student to Graduate
A. N. Senanayake.

LEEDS SECTION
As Associate Member
A. T. Grierson.
As Graduate
N. Jagger.
As Student
K. E. Davies.
Transfers
From Graduates to Associate Members
A. Cross; W. P. Barker
From Students to Graduates
A. W. Medley; J. Fairbrother.

LEICESTER SECTION
As Associate Members
P. H. Morris; R. P. Bowles.
As Graduates
T. J. Lawson; G. R. Staples; M. S. Warnes; R. N. Barikipati; M. G. Saunders.
As Students
M. F. Falkner; G. S. Grewal; R. Leigh; P. G. MacKey; A. H. Wood; P. K. Chadha
Transfers
From Graduates to Associate Members
M. G. Grant; J. W. Ramsden.

LINCOLN SECTION
As Student
A. Brown.

LIVERPOOL SECTION
As Graduate
E. A. Jones.
Transfers
From Graduate to Associate Member
V. K. Burley.
From Student to Graduate
B. Sixsmith.

LONDON SECTION
As Members
M. Tomkowicz; J. T. Ratcliffe.
As Associate Members
L. J. Cook; G. T. Schwartz; W. J. Kease; A. R. Kennedy; R. Heygate; D. E. E. French.
As Associate
R. W. Taylor
As Graduates
D. Pett; T. A. Caston; G. T. Jarman; M. T. Cullen; A. Smith; G. A. Trott; R. J. Hicks; A. J. Sharp; B. W. March; N. R. M. Webster; N. D. Black; P. E. Streamer; C. Bryant; J. Proctor; A. E. Gross-Balthazard; L. W. Coleshill; T. P. Russell; P. H. Rollason; R. H. Slee; R. A. Mercer; D. R. Waddell; B. R. Clark; C. H. Dudeney; L. C. Lambert; C. C. Denty; R. J. Brigden; B. F. A. Lane.
As Students
W. T. A. Foster; D. R. Parfitt; D. White; J. N. Galley; P. F. Adams; L. C. King; D. W. Dickson; J. A. R. Abbott; D. J. Pinchen; M. G. Gilbert; M. J. Duffy; C. Phillips; T. W. J. Porter; P. J. Ship; D. O. A. Elmer; P. K. Sowter; C. V. King; M. Hammond; B. J. Wilshin; G. L. Sewell; J. E. Price; B. E. Marchant; S. R. Tomlin; I. V. Anthony; A. G. Usherwood; B. Helbrough.
Transfers
From Associate Members to Members
C. L. Collis; G. I. Robinson; D. G. Gohm; J. C. Ward; F. C. Bambridge; J. Selby.
From Graduates to Associate Members
A. J. King; R. E. Stone; J. W. Martin; C. A. Jones; B. J. Allen; R. S. Jagger; A. F. Jordan; C. H. John; P. C. Felton; P. A. T. Arrigoni; R. L. Goldsmith; A. L. Threader.
From Students to Graduates
J. P. Brennan; J. V. E. Lindquist; R. H. Stubbs; G. Anson; P. W. Shipton; M. W. Rossiter; D. V. Shaw; D. R. Drew; P. D. Robinson.

LUTON SECTION
As Graduates
M. J. Sage; C. J. Vidall; J. Currant; D. Ward; R. V. Spratt; G. T. Polding; W. H. Roberts; I. B. Fraser; D. H. Fear.
As Students
M. B. Jeffries; R. W. Greene; G. R. Jones; B. E. Wootton; A. R. Organ; R. H. Perry; B. Etherington; P. F. Blott; J. C. Baker; B. A. Hammond; P. W. Ware; J. T. Coulter.
Transfers
From Students to Graduates
R. V. Perry; E. L. Amiss; W. S. Lane; D. N. Williamson; L. E. Almond; J. W. Miller; R. G. Joyner.

MANCHESTER SECTION

As Graduates
K. A. P. Toolan; B. Marsh; J. Davison; H. S. Gupta; J. Clarke; J. Lawton.
As Students
C. F. Molyneux; G. B. Harris.
Transfers
From Graduates to Associate Members
R. Fletcher; S. S. A. Duncan; R. Whitehead.
From Students to Graduates
J. T. A. Morris; G. S. Catterall; B. Hunt; R. E. Percival; F. Thomasson; J. W. Touhey.

MELBOURNE SECTION

As Member
J. M. McLennan.
As Associate Members
R. F. Harris; D. Beard.
As Graduates
J. H. Henderson; J. A. C. Taws; C. C. McNeil.
As Students
A. G. Watson; G. L. Peverell; M. W. Chik; C. C. Chapman; F. H. Sawatzky; S. C. S. Cheng; H. Knol; J. W. Sherlock; J. E. Hunt; A. Oliver; H. K. Chen; J. E. Noble.
Transfer
From Student to Graduate
F. A. Roberts.

NEWCASTLE ON TYNE SECTION

As Graduates
J. C. Jobling; G. E. Wallace; M. Enright; M. Hope; A. C. Chisholm; M. Scott.
As Student
J. Parnaby.
Transfers
From Associate Member to Member
R. G. Monkhouse.
From Graduates to Associate Members
R. Vipond; J. F. Hedley; H. E. A. Noble.
From Student to Graduate
R. J. Carr.

NOTTINGHAM SECTION

As Graduates
B. Leavesley; K. A. Pounder
As Students
S. Banks; J. A. Beck; A. Summers.

OXFORD SECTION

Transfers
From Associate Member to Member
J. Winstone.

PETERBOROUGH SECTION

As Students
T. C. Gilbert; R. J. Read.

PRESTON SECTION

As Associate Members
J. T. Hughes; J. A. Burton.
As Graduates
A. Atkinson; N. Beaumont; R. Sutcliffe; D. Valentine; A. Gunton; B. McDonagh
As Students
P. Joinson; R. E. Dickinson.
Transfers
From Graduates to Associate Members
A. Ormerod; N. Dooley; M. A. Goody.
From Students to Graduates
T. Lowe, J. Edmondson; W. H. Busby.

READING SECTION

As Associate Member
C. E. McLoughlin.
As Graduates
J. C. Duncombe; B. C. Tothill.
As Student
H. B. Cooper.

Transfers
From Associate Member to Member
W. G. Dorkings.
From Graduate to Associate Member
M. R. Hulbert.

ROCHESTER SECTION

As Student
L. R. King.

SHEFFIELD SECTION

As Members
H. Bull; D. Johnston.
As Associate Member
A. S. Dodds.
As Graduate
H. Stokes.
As Students
J. Almond; B. P. Jeremiah; R. O. Baxter; A. A. Tyrer.
Transfers
From Associate Member to Member
A. N. Guylee.
From Graduate to Associate Member
R. D. Hind.
From Student to Graduate
V. S. Eltringham.

SHREWSBURY SECTION

As Graduates
G. T. Jones; R. J. Cook.
As Student
D. T. Barnett.

SOUTHAMPTON SECTION

As Associate Member
M. G. Wheat.
As Graduates
G. H. Stables; S. Sen Gupta.
As Students
P. K. Mathur; M. H. Espezel; J. H. W. Lewis.
Transfers
From Associate Member to Member
P. J. Edwards.
From Graduate to Associate Member
C. G. J. Gould.
From Graduate to Associate
E. C. Spurr.
From Students to Graduates
A. Morton; B. H. Drake.

SOUTH AFRICA SECTION

As Members
E. L. Harris; R. A. Heugh.
As Associate Members
K. C. Orphan; R. D. Merrygold.
As Graduate
P. R. Webber.
As Student
A. D. Havenga.
Transfer
From Graduate to Associate Member
E. D. Montgomery.

SOUTH ESSEX SECTION

As Graduates
D. E. Hilsley; C. W. Chapman; J. E. Fell; C. H. Powell; D. R. Pigden; H. S. Edwards.
As Students
J. Swift; T. G. Rata; M. A. Woodcraft; R. A. Cook; E. Barrett.
Transfers
From Associate Member to Member
H. F. Maton.
From Graduates to Associate Members
D. A. H. Pennick; H. W. Smith.
From Students to Graduates
P. West; R. W. Sach.

STOKE-ON-TRENT SECTION

Transfers
From Graduates to Associate Members
G. E. Jackson; W. H. Roberts.

SWANSEA SECTION

As Graduate
A. Jones.
Transfer
From Graduate to Associate Member
G. J. Aries.

SYDNEY SECTION

As Associate Member
J. A. Wallis.
As Graduate
R. R. Crawford.
As Student
A. D. Walker.

TEE-SIDE SECTION

Transfer
From Graduate to Associate Member
K. Hancock.

WESTERN SECTION

As Associate Member
M. B. Pelly.
As Graduates
T. H. Gwynn; D. H. Thayer; C. F. Holding; P. D. H. Warr; L. Twineham; M. C. Russell.
As Students
R. W. E. Rowsell; J. J. Skinner; C. R. Butt; D. L. Tucker; J. W. Charles; T. G. Michell; M. V. L. Oliver.
Transfers
From Students to Graduates
B. O. Jenkins; M. C. Skinner; P. H. Wells; D. E. Vowles; D. L. Giles; R. E. Hopkins; D. W. Eggbeer, A. J. F. McAlinden; J. A. Hobbs; D. W. Ragbourne.

WOLVERHAMPTON SECTION

As Member
A. M. Leslie.
As Associate Member
J. M. Richards.
As Graduates
R. W. Badland; L. M. Gleed; S. S. Lota; J. T. Fleeming; J. A. Fawdry; W. F. Hand; W. E. Bourne; W. M. Tomlinson; Q. Sproule; T. McCarthy; R. S. Sutherland; R. G. Phillips; J. A. Sugden; B. J. Lloyd; K. W. Cadman; R. Purcell; J. Burrows; G. J. Evans; B. Ball; R. G. Sanders; P. Graystone; J. G. Price; F. Andrews; S. S. Sandhar; R. W. Bradley; V. G. Smith; R. Millington; R. A. Williams; L. J. Yates; J. V. Roberts; E. T. Round.
As Students
B. W. Peters; R. J. Wilcox; B. Timmis; R. Mackenzie; H. W. Dobie; A. Corbett; G. E. Tooth; B. Jones.
Transfers
From Graduates to Associate Members
K. Davies; A. Hoyle; R. G. Clark; A. Grifiths; I. R. Jones; J. Metcalfe; A. B. Caine.
From Students to Graduates
D. N. Byard; C. C. Hopkins; P. Westwood; L. Kureishi; J. A. Wilkes.

NO SECTION

As Graduate
P. H. Mann.
As Student
M. R. Singh.
Transfers
From Associate Member to Member
R. A. M. Farman.
From Graduate to Associate Member
H. F. Gadd.
From Students to Graduates
J. C. Laing; R. J. M. Fisher.

Correspondence and comment on published Papers and matters of interest to production engineers are invited.
Communications should be addressed to :

THE EDITOR,
"THE PRODUCTION ENGINEER,"
10 CHESTERFIELD STREET,
MAYFAIR, LONDON, W.1.

institution notes

NEW INDIAN SECTION

The Bangalore Section of the Institution, which was formally inaugurated in December last, is now firmly established, and its activities have aroused much local interest. The first Chairman is **Mr. R. L. Kapoor,** M.I.Prod.E., A.M.I.E.(Ind.), and the Hon. Secretary is **Mr. G. N. Advani,** B.E., A.M.I.Mech.E., A.M.I.Prod.E.

The inaugural ceremony was performed by the Vice-Chairman of the Indian Council, **Mr. Alec Miller,** who said, in his opening address, with regard to greater productivity in India, that the amount of electric power available was a secondary consideration, for machines and electric power would be of little use without experienced production engineers. For every machine in the country, he said, two engineers were required and that, in itself, should give some idea of the importance of training production engineers.

After referring to training facilities, present and future, Mr. Miller concluded his address by emphasising that it was the duty of the production engineers at present working in India to train others, and in doing so, to give this service without expecting any personal reward. Their job would be to make production engineers of whom the country might well be proud.

Following the reading of a Paper on " Industrial Productivity and Management " by **Mr. S. M. Patil,** B.S.(Mech.), B.E.(Elec.), M.I.E., M.I.Prod.E., General Manager of Hindustan Machine Tools, Bangalore, the meeting concluded with a dinner.

CANADIAN PRODUCTION EXHIBITION

The Institution of Production Engineers will be well represented at the Conference which has been arranged to run concurrently with the National Industrial Production Exhibition in Toronto, from 8th - 12th May next.

Mr. D. L. Nicolson, Managing Director of Production-Engineering Ltd., who are affiliated to the Institution, is to present a Paper on "International Productivity Co-operation in the Design and Planning of Factories", and **Mr. K. Trickett,** also a Director of the firm, will speak on "Investing in Better Materials Handling". A third Paper will be given on "Measuring Materials Handling Work", by **Mr. J. Brown,** of Woods-Gordon Ltd., associated to Production-Engineering Ltd., in Canada.

A further Paper on "MCT Operating Systems" will be given by two members of the Canadian Section. This has been arranged by **Mr. S. Carroll,** Chairman of the Section.

In addition, the Secretary of the Institution, **Mr. W. F. S. Woodford,** is to deliver a theme address on "International Co-operation for Productivity in the Future".

Mr. Woodford will be in Canada for about three weeks, and will take the opportunity of discussing Institution matters with the officers and members of the Canadian Section, and of exploring the possibility of establishing a new Section in Montreal. He will also visit a number of industrial concerns and establishments.

Members of the new Bangalore Section, photographed with Mr. Alec Miller, Vice-Chairman of the Indian Council, at the inaugural meeting.

Newcastle upon Tyne Dinner Dance

18th January, 1961

Right: **Mr. A. Cameron, Northern Regional Chairman, with Mrs. Cameron and Mr. W. F. S. Woodford, Institution Secretary.**

Far right: **Sir William Scott, O.B.E., J.P., Chairman, Armstrong - Whitworth (Metal Industries) Ltd., with Lady Scott.**

Right: **Major C. E. Darlington, Section Chairman, with Mrs. Darlington; Major-General K. C. Appleyard, C.B.E., Past President of the Institution; Mrs. Howard and Mr. W. N. Howard, Director of Education, Gateshead.**

DIARY FOR 1961

APRIL 22 ... ... **North Midlands Regional Conference, Peterborough.***
Subject: **" The Human Element and Productivity "**

APRIL 26 ... ... **The 1960 George Bray Memorial Lecture, Olympia, London.***
Speaker: **Mr. H. Silman,** B.Sc., F.R.I.C., M.I.Chem.E., F.I.M., Past President, Institute of Metal Finishing; Director, Electro-Chemical Engineering Co. Ltd.
Subject: **" The Protective Treatment of Metals against Corrosion "**

MAY 5 ... ... **Wales Regional Conference, Cardiff.***
Subject: **" The Conservation of Materials "**

MAY 24 ... ... **Region and Section Officers Conference, 10 Chesterfield Street, Mayfair, London, W.1.**

JUNE 14 ... ... **The 1961 Viscount Nuffield Paper, University of Bristol.***
Speaker: **Sir Willis Jackson,** Director of Research and Education, A.E.I. (Manchester) Ltd.

NOVEMBER 1 ... ... **Annual Dinner, Dorchester Hotel, London.**

* see Journal Supplement.

news of members

Mr. Robert Appleby, Member, who is Managing Director of Black & Decker Ltd., Harmondsworth, and a Director of Black & Decker subsidiaries in Belgium, West Germany and The Netherlands, has been appointed to the newly-created office of Executive Vice-President — European Operations, of The Black & Decker Manufacturing Co.

Mr. John H. Dex, Member, Technical Director of Thomas Robinson & Son Ltd., Rochdale, has now retired, but he will continue his association with the Company in a technical advisory capacity. He joined the Company in 1910 as an apprentice.

Mr. J. Finlay, Member, and Past Chairman of the Sydney Section, has been awarded the American Society of Tool & Manufacturing Engineers Engineering Citation and Medal for 1961. Mr. Finlay was the first Chairman of the Sydney Chapter of the American Society of Tool & Manufacturing Engineers, and the award was made for his outstanding contribution to Production Engineering Tooling in Australia.

Mr. Sydney Francis, Member, formerly Chairman and Managing Director, Brontalloy Ltd., Leeds, is now in business as a Consultant.

Mr. E. H. Holder, Member, Principal Production Officer, D.A.W.P., London, has been transferred to R. E. P. Wescott, Bucks., in charge of Engineering.

Mr. C. E. Jones, Member, Managing Director of Sonnerdale Ltd., Gear Manufacturers, Sydney, Australia, will be visiting the United Kingdom from April to September, when he leaves for the U.S.A. Mr. Jones joined The Institution of Production Engineers in 1944 and was a member of the Committee of the Sydney Section from 1946 - 1951, when he was elected President. He has presented several Papers dealing with broaching, gear manufacture and the use of tungsten carbide cutting tools.

Mr. A. D. Lidderdale, Member, has been appointed General Manager of Leybold-Elliott Ltd., the Company recently formed by Elliott Brothers (London) Ltd. and Leybold's of Cologne.

Mr. A. E. Reddell, O.B.E., Member, has retired from the Board of Directors of Vickers-Armstrongs (Engineers) Ltd. and from his office of Director-in-Charge of the Weymouth Works of that Company.

Mr. Alex Sykes, Member, has relinquished his position as a Senior Engineer and Chief Inspecting Engineer with Rendel, Palmer & Tritton, and has taken up an appointment as Managing Director of Morris & Butters Ltd.

Mr. W. Washbourne, Member, has relinquished his position as General Works Manager with The Wolverhampton Die Casting Co. Ltd. to rejoin Newton Chambers & Co. Ltd., Thorncliffe, as General Manager, Excavator Division.

Mr. D. E. Banham, Associate Member, has joined Precision Gear Machines & Tools Ltd., Red Ring Works, Coventry, as Works Manager. For the past six years he has held the post of Consultant with Associated Industrial Consultants Ltd.

Mr. M. B. Cotton, Associate Member, has recently taken up an appointment as Chief Engineer with The Plessey Company, Havant, Hants.

Mr. D. Dawson, Associate Member, who was formerly Head Jig and Tool Designer at Davey & United Engineering Co. Ltd., Sheffield, is now Design Engineer in the Company's newly-formed Design for Production Liaison Group.

Mr. A. E. Dupree, Associate Member, has recently taken up an appointment as Joint Managing Director with Nico Light Co. Ltd., Birmingham. Mr. Dupree was, until recently, Chairman of the Institution's Materials Handling Group Committee.

Mr. Kenneth Grant, Associate Member, Assistant General Manager of Peter Brotherhood Ltd., has been appointed to the Board.

Mr. R. D. Guthrie, Associate Member, Works Controller of Radiation (New Zealand) Ltd., has been appointed to the Board.

Mr. H. T. Hill, Associate Member, is now Managing Director of his Company, Wellworthy Ltd., Lymington, Hants.

Mr. E. A. Mauskopf, Associate Member, has relinquished his position with E. M. Tool Co. Ltd. and has taken up an appointment as Designer in the Development Department of Chiswick Products Ltd., London.

Mr. D. McPhail, Associate Member, has taken up the position of Senior Lecturer in Production Engineering at the Lanchester College of Technology, Coventry.

Mr. H. F. Rudkin, Associate Member, has relinquished his appointment with The Sperry Gyroscope Co. Ltd. in order to take up a position in The National Institute for Research in Nuclear Science. He is at present working at the Rutherford High Energy Laboratory, Harwell, where he is in charge of the Estimates Section.

Mr. P. R. Shanker-Narain, Associate Member, is spending two years in the United Kingdom, working as a Production Engineer in The Metal Box Co. Ltd., Mansfield.

Mr. W. Bruce, Graduate, has moved to a new appointment as Sales Manager of Limi-Torque Valve Controls Ltd., from the parent Company, Opperman Gears Ltd., which he joined in 1951 as a Technical representative.

Mr. N. Chakrabarty, Graduate, has relinquished his position with Joseph Lucas Ltd., Birmingham, and has taken up an appontment as a Senior Executive (Production) with Sankey Electrical Stampings (Private) Ltd., Rajajinagar, Bangalore, India.

Mr. B. Johnson, Graduate, formerly Tooling Engineer with Borgwarner Ltd., is now Chief Planning Engineer at the Automatic Transmission Division of Gresham & Craven Ltd.

Mr. D. E. Rogers, Graduate, has relinquished his position as Methods Engineer with English Electric Co. Ltd., Stafford, to take up an appointment as Assistant Production Engineering Works Manager with Doulton Industrial Porcelain Ltd. Tamworth, Staffs.

Mr. S. Shanmugan, Graduate, is now Engineer-in-Charge of Southern Industrial Corporation Ltd., Madras.

Mr. J. I. Sundararaman, Graduate, has, after completing three years training with Massey-Ferguson (U.K.) Ltd., taken up an appointment as Engineer-in-Charge with Tractors and Bulldozers (Private) Ltd., Baroda, P.O., India.

Obituary

The death of **Mr. J. J. Gleeson,** Member, of the Rochester Section, is recorded with deep regret.

Mr. Gleeson, who was a founder member of the Section, had been active in Institution affairs for many years, and his enthusiasm and unfailing support contributed in no small measure to the establishment and development of the Rochester Section. He was held in high regard and affection by his many friends and colleagues in the area, and his passing is a sad loss not only to the Institution, but to the profession of production engineering.

At the time of his death, Mr. Gleeson was Production Engineer of Blaw-Knox Ltd., Rochester.

Institution Provident Scheme

In July, 1957, the Institution arranged a group scheme with the British United Povident Association in order to give members the opportunity of providing against the heavy costs of the private treatment of illness and accident. There are three age groups and five scales of benefit designed to give adequate cover throughout the United Kingdom. The benefits are also available while temporarily abroad on business or holiday. By joining the group members become entitled to membership of B.U.P.A. with the additional advantages of:

(a) immediate benefit on acceptance, the usual three months' waiting period being waived;
(b) a subscription rebate of 20%.

In addition, an optional extension is available by which members of the group may cover themselves against the cost of private general practitioner treatment.

Applications and enquiries should be addressed to: The Secretary, 10 Chesterfield Street, London, W.1.

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ADDITIONS

American Welding Society, New York. **"Soldering Manual."** *New York, the Society,* 1959. 170 *pages. Illustrated. Diagrams. Tables.* 46s. 0d.

Contents: Principles of soldering — Solders — Fluxes — Joint design — Precleaning and surface preparation — Equipment, processes and procedures — Flux residue treatment — Inspection and testing — Copper and copper alloys — Steel — Coated steels — Stainless steels — Nickel and high-nickel alloys — Lead and lead alloys — Aluminium and aluminium alloys — Magnesium and magnesium alloys — Tin — Cast irons — Precious metal coatings — Printed circuits — Safety.

Baker, H. Wright (editor). **"Modern Workshop Technology." Part 2—"Machine Tools and Manufacturing Processes."** Second edition. *London, Cleaver-Hume Press,* 1960. 650 *pages. Illustrated. Diagrams. Tables.* 55s. 0d.

A considerable revision of the first edition of this standard work, which now includes a preliminary chapter by Doctor Koenisberger on the basic principles of machine tools and metal cutting, and information about recently developed processes, such as spark erosion machining and ultrasonic machining. As in the first edition all chapters are written by specialists in their respective subjects. The second edition of Part 1 (Materials and Processes) was published in 1956; and an entirely new Part 3, on production planning and automatic machines is in preparation.

Contents: Metal cutting machine tools — The theory of cutting tools — Turning — Milling — Drills and drilling machines — Broaching — Shaping, planing and slotting — Precision grinding — Ultrasonic machining — Screw thread production — Gears and gear cutting — Electric machining of metals — Sheet metal drawing; load conditions of blanking and deep drawing operations — Presswork — Measurement standards and equipment — Inspection — The measurement of surface texture — Jigs and fixtures — Friction lubrication and cutting fluids — Heat treatment appliances — Elements of production engineering — Principles of standardisation — Safety devices — Human relations in the workshop — Bibliographies and references —Metric conversion factors.

British Institute of Management, London. **"Education and Training in the Field of Management."** Fourth edition. A conspectus of management courses. *London, Pitman, for the Institute,* 1960. 287 *pages.* 45s. 0d.

An attempt to provide a comprehensive coverage of facilities for management training in the United Kingdom. Part 1 is an index to educational establishments including universities, colleges, adult education centres, professional organisations and other organisations, which provide short or long courses on subjects in any way related to management. Part 2 is a subject index giving fuller details of these courses; Part 3 gives information on the degree and diploma courses containing management subjects; and Part 4 gives information on the syllabuses of professional and other bodies which conduct examinations in the field of management.

Canning, W., & Co. Ltd., Birmingham. **"Canning Handbook on Electroplating, Polishing, Bronzing, Lacquering."** Nineteenth edition. *Birmingham, the Company,* 1960. 631 *pages. Illustrated. Diagrams.*

A comprehensive handbook upon the experience of the company which manufactures electroplating and other finishing machinery.

Seymour, W. Douglas. **"Operator Training in Industry."** *London, Institute of Personnel Management,* 1959. 52 *pages. Illustrated. Diagrams.* 7s. 6d.

Discusses with many examples drawn from various industries the training of skilled and semi-skilled workers. Unskilled and semi-skilled occupations are defined for the purpose of the pamphlet as those for which time-served apprenticeships are not required.

Contents: Introduction (summarising the types of work usually undertaken by skilled and semi-skilled workers — Manual skills — Handwork operations — Handwork with tools — Single purpose machine work — Multi-purpose machine work — Group machine work — Non-repetitive work — Personnel objectives in operator training.

Shaymian, G. A. **"Some Questions on the Building of Automatic Machine Tools."** *Moscow,* 1955. 210 *pages. Diagrams.* In Russian.

The author is Professor of Machine Tools at the Moscow High Technical School, Baumen, and this book is compiled by himself and members of his staff. Solutions are given to various theoretical problems in the building of automatic machine tools.

Vladzievsky, A. P. **"Automatic Transfer Machines."** *Moscow,* 1958. 2 *vols.* 427 *pages,* 338 *pages. Diagrams.* In Russian.

Descriptions of Russian and other automatic transfer machines. The principles of design are expounded, and the various types of automatic transfer machine are analysed and classified.

Wakefield, C. C. and Company Limited, London. **"Hydraulic Oils."** *London, the Company,* 1960. 71 *pages. Diagrams.*

Deals with the "many aspects of the transmission of power by means of liquids." One chapter is devoted to the properties and selection of mineral oils for power transmission.

Contents: Historical development — Fundamental principles — Hydraulic pumps and motors — Components of hydraulic circuits — Hydraulic fluids.

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Industrial Sociology and Methods of Social Enquiry
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Quality Control
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Admission to these courses is limited. Enquiries for further details and applications for admission should be directed to :

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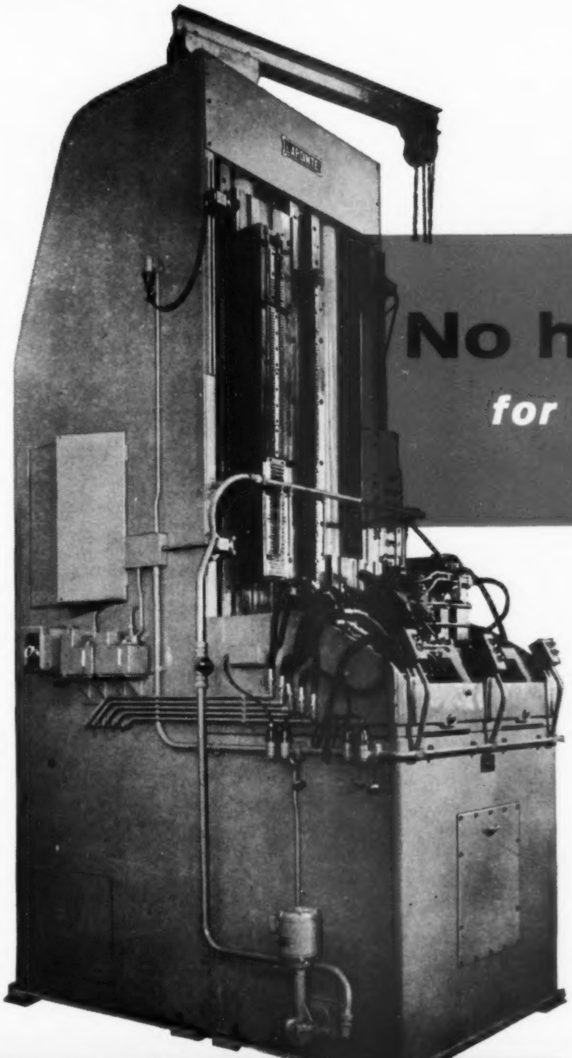

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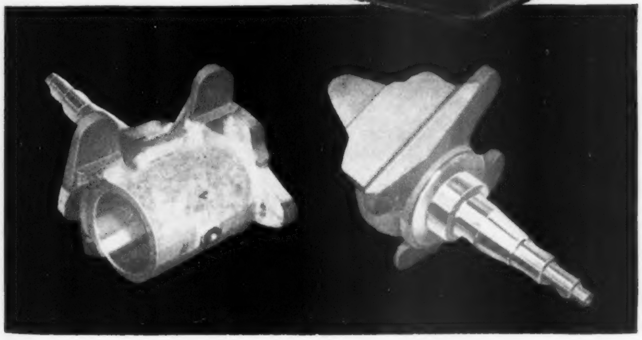

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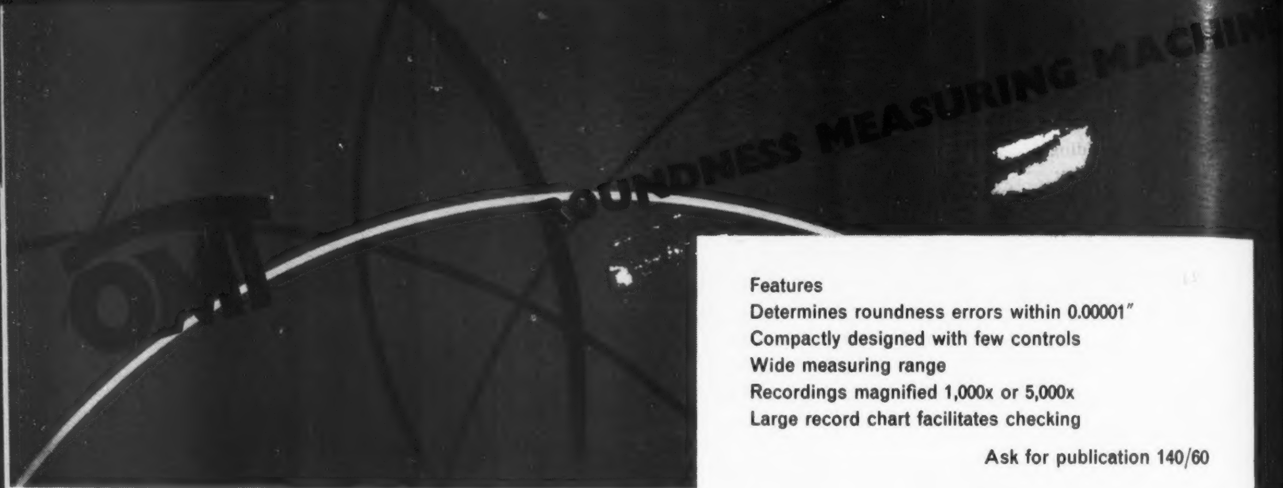

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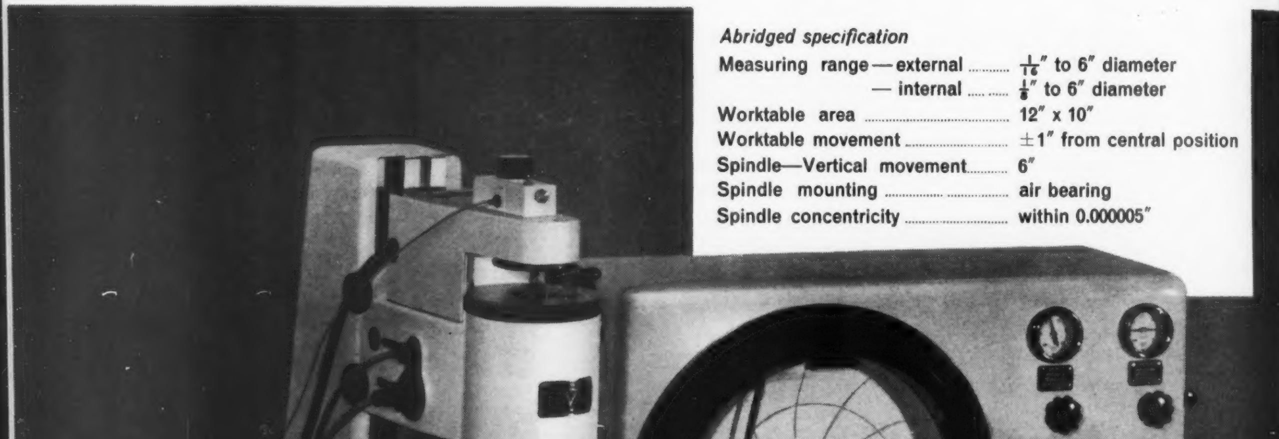

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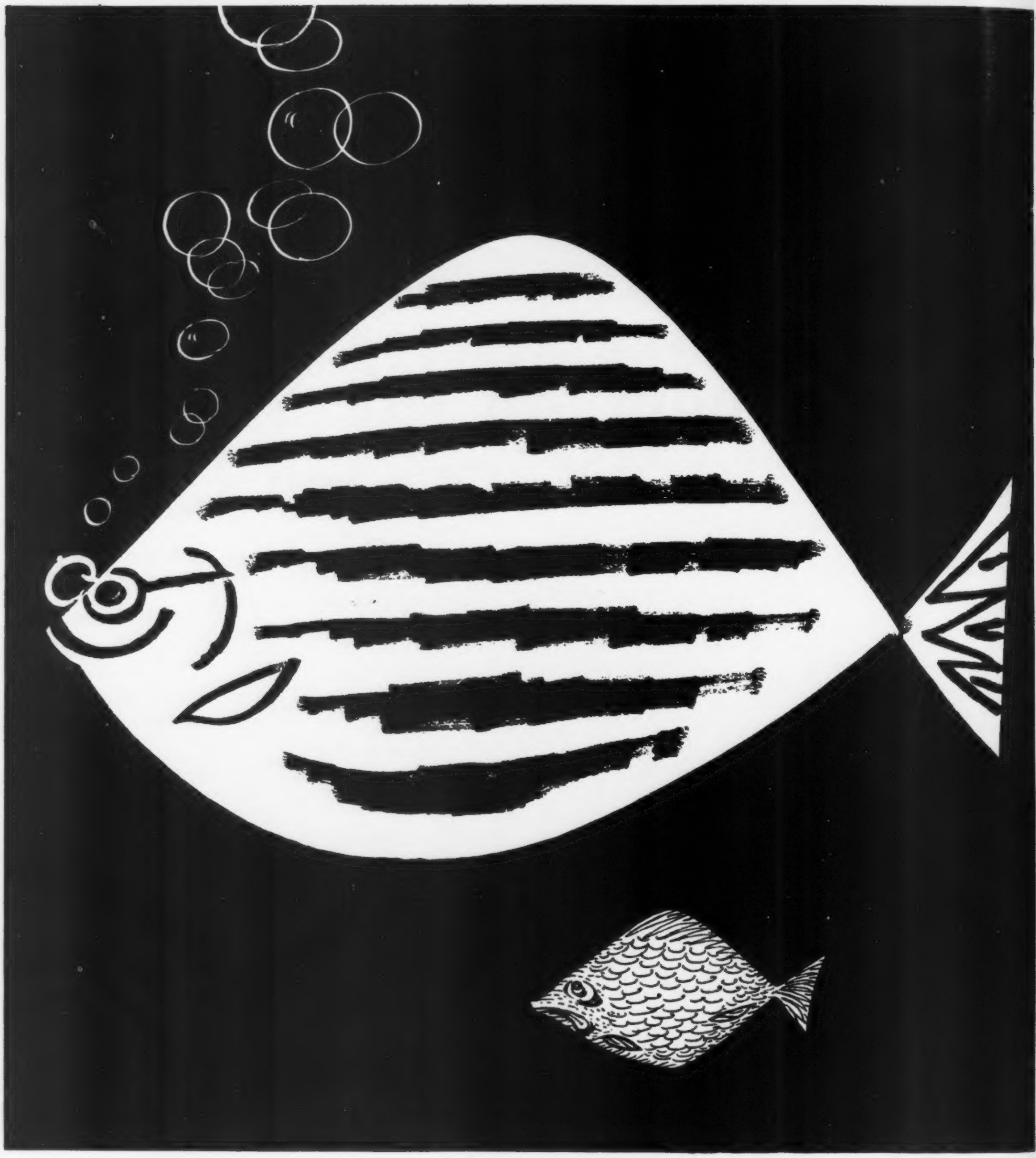

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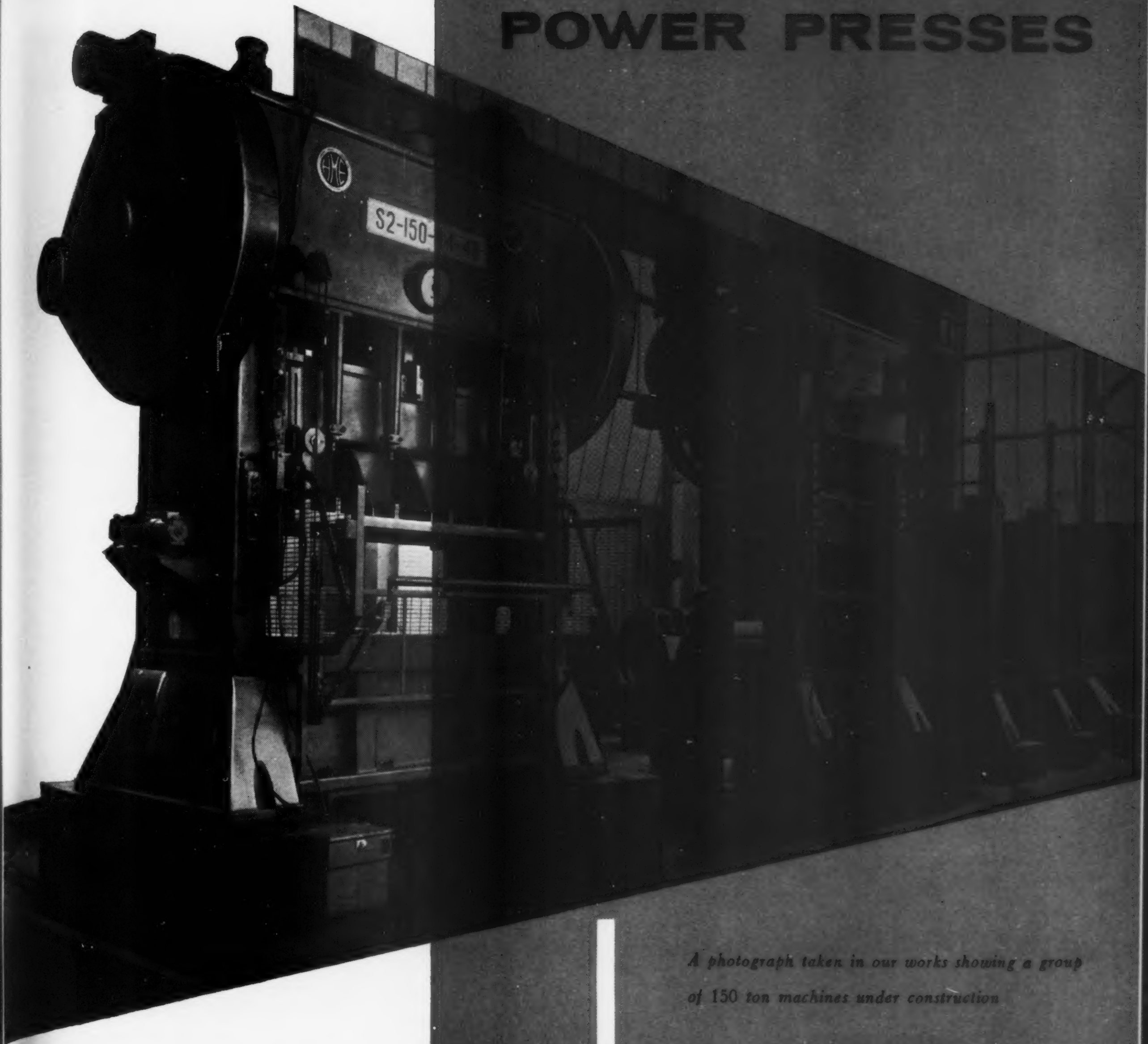

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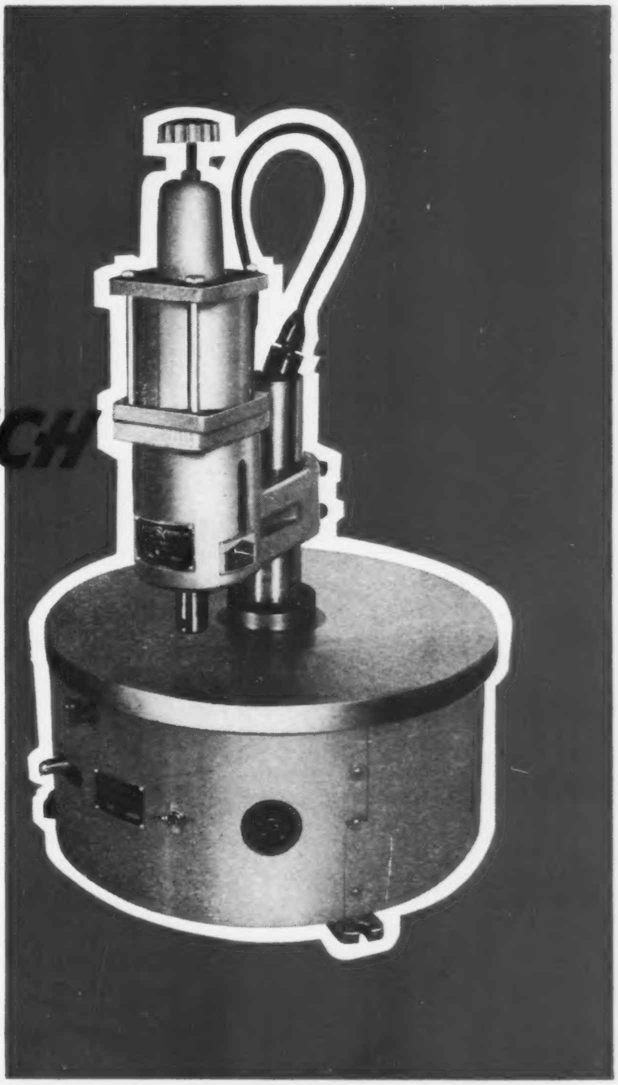

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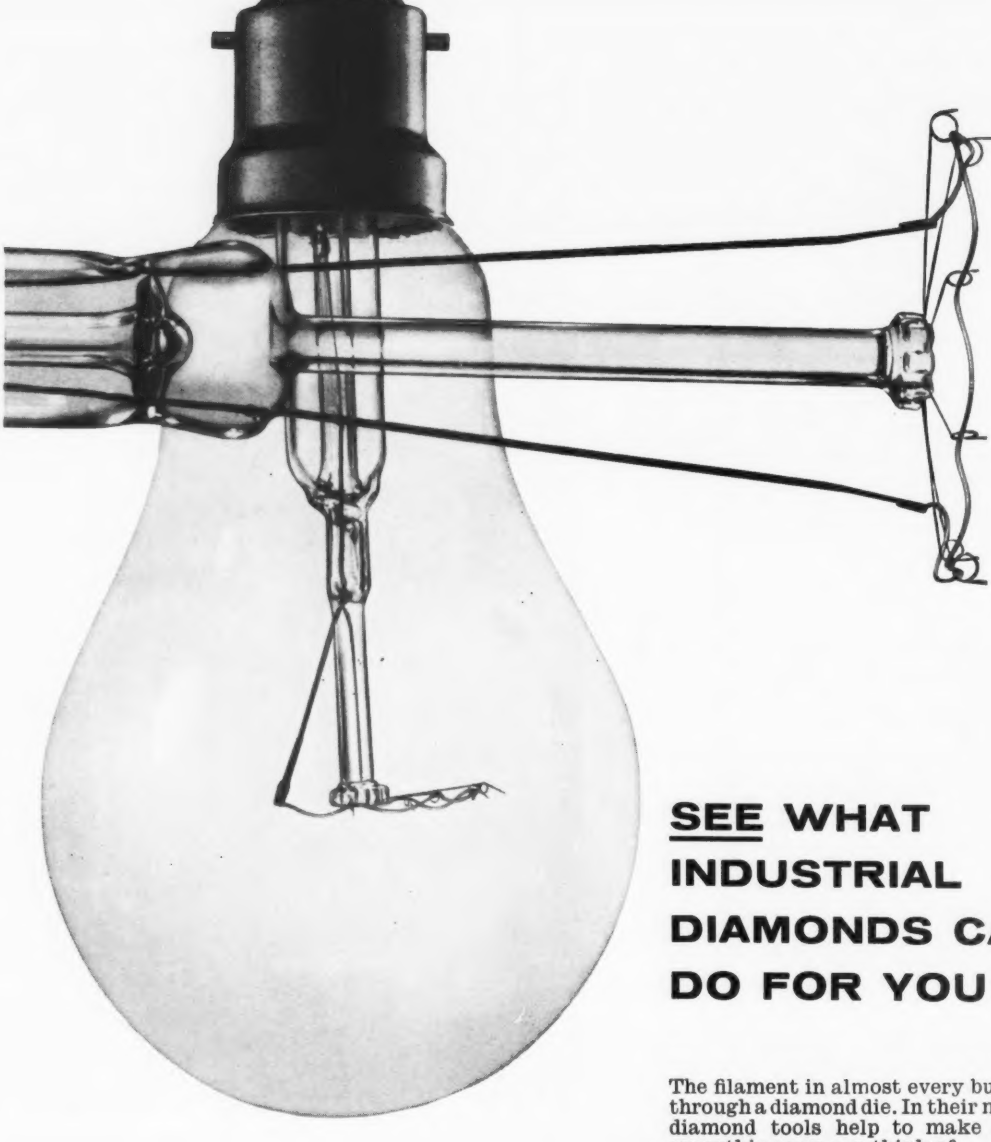


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The Lincoln SPRITE CO_2 Welding Unit, showing the Remote Amperes Control Box for 'on the spot' control of welding current and the Lincoln FW.1 CO_2 Hand Welding Gun.
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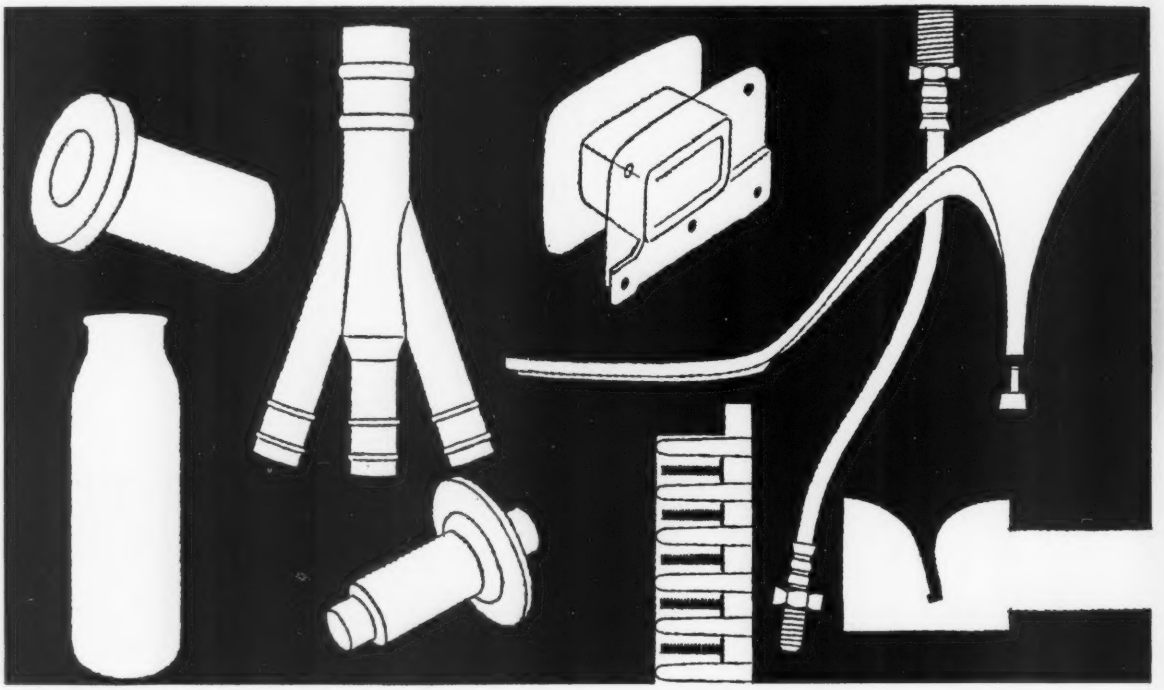

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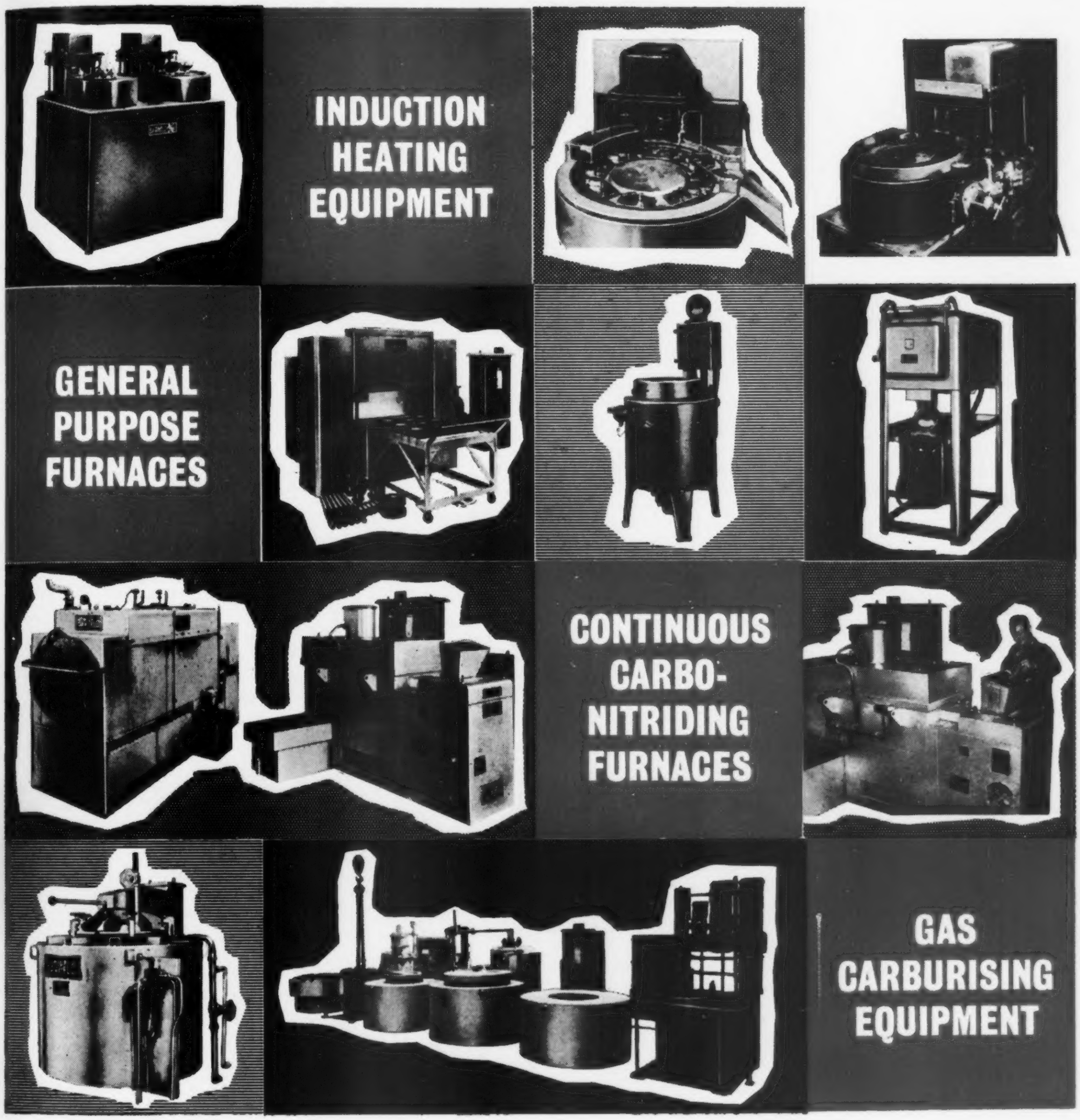
UH51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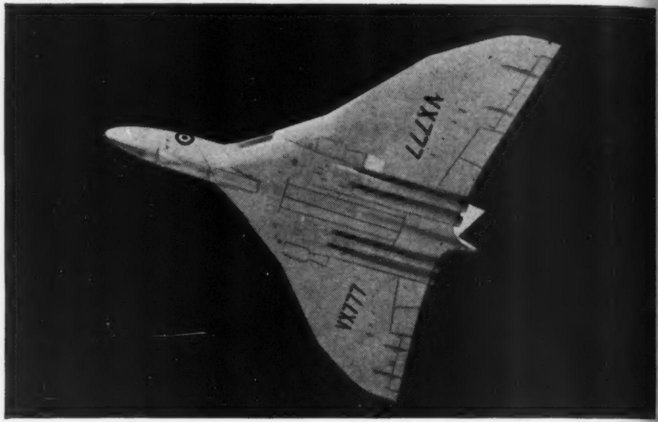
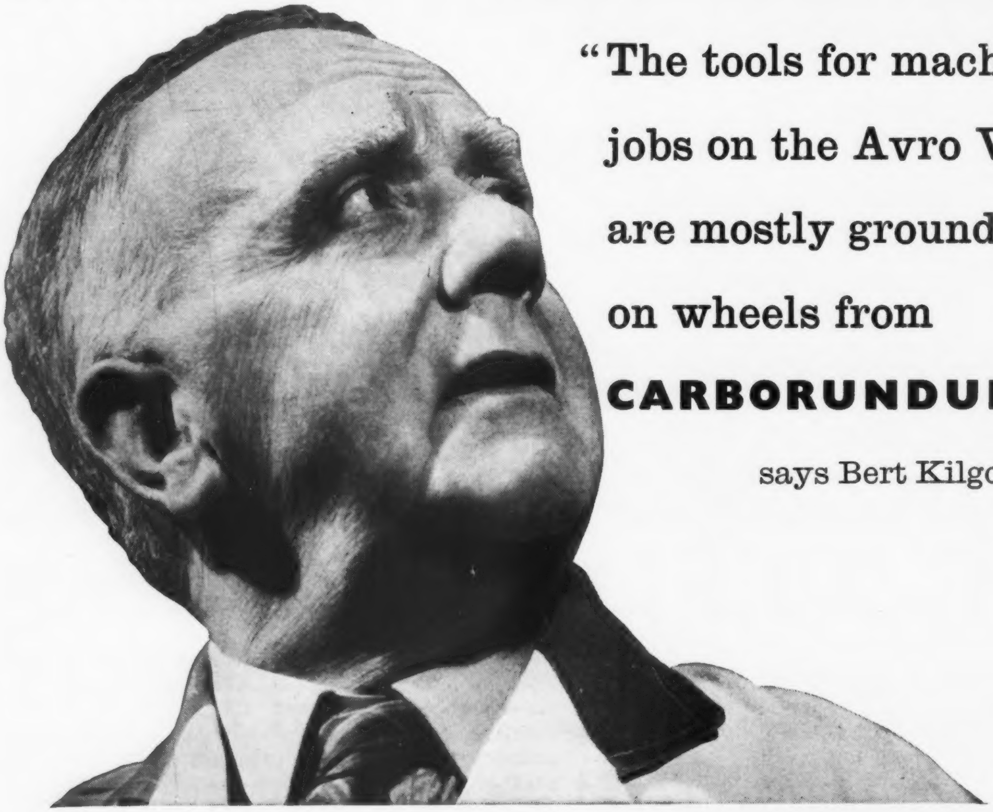
Bert Kilgour has worked at the main factory of A. V. Roe & Co. Ltd, at Chadderton, for 40 years, and is now the senior foreman of the toolroom, in which 300 men are employed: "Must be one of the biggest toolrooms in the country," Bert says. "We started getting grinding wheels from CARBORUNDUM in 1936, and they've supplied most of our wheels ever since then. That's for the whole factory — not just the toolroom. Why? Well, because their wheels do a good job, and give us good service. They've always been ready to help us when we've asked them to."





"The tools for machining jobs on the Avro Vulcan are mostly ground on wheels from CARBORUNDUM"

says Bert Kilgour

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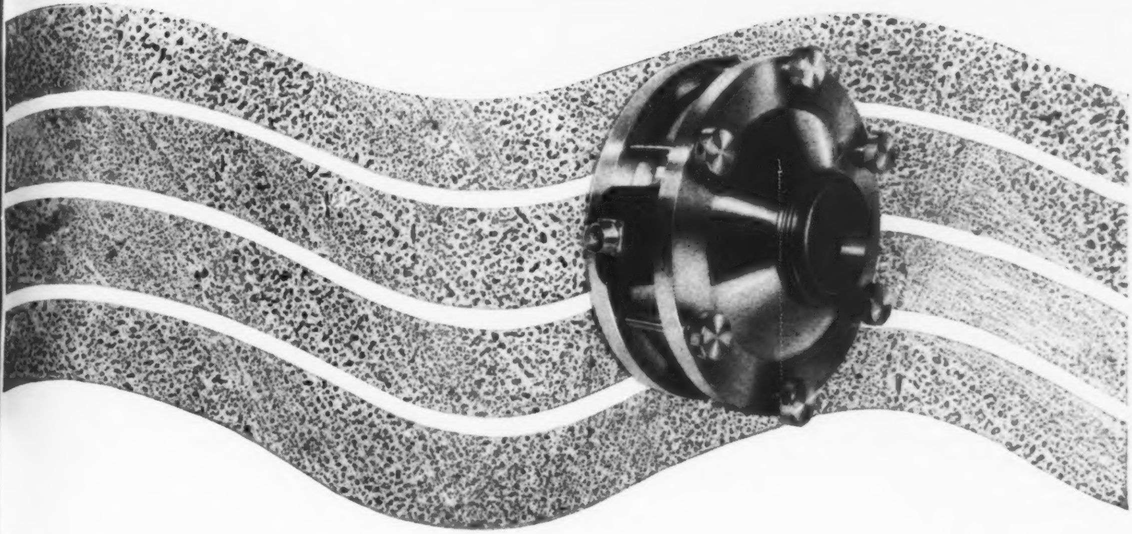

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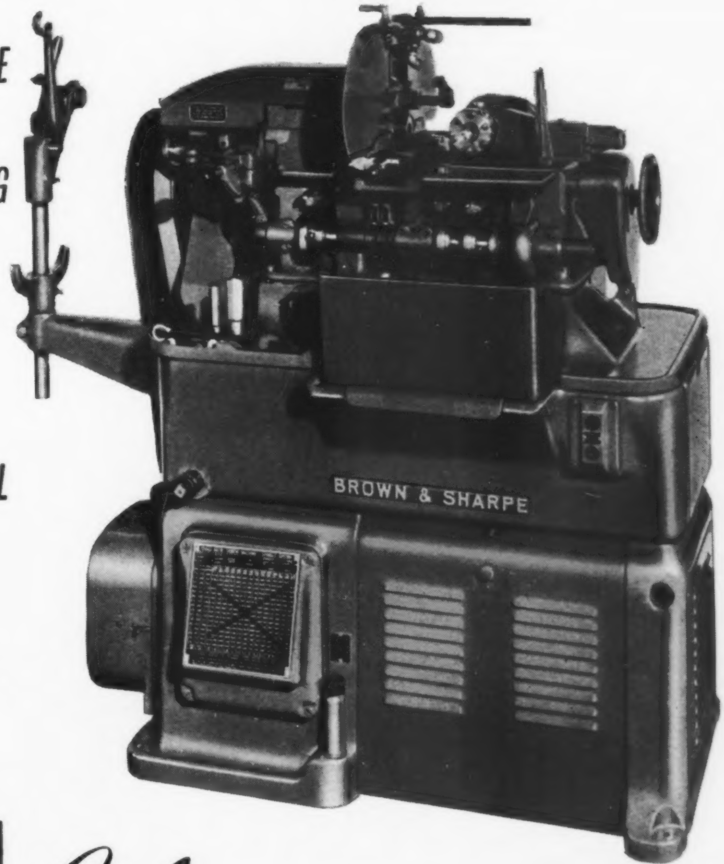

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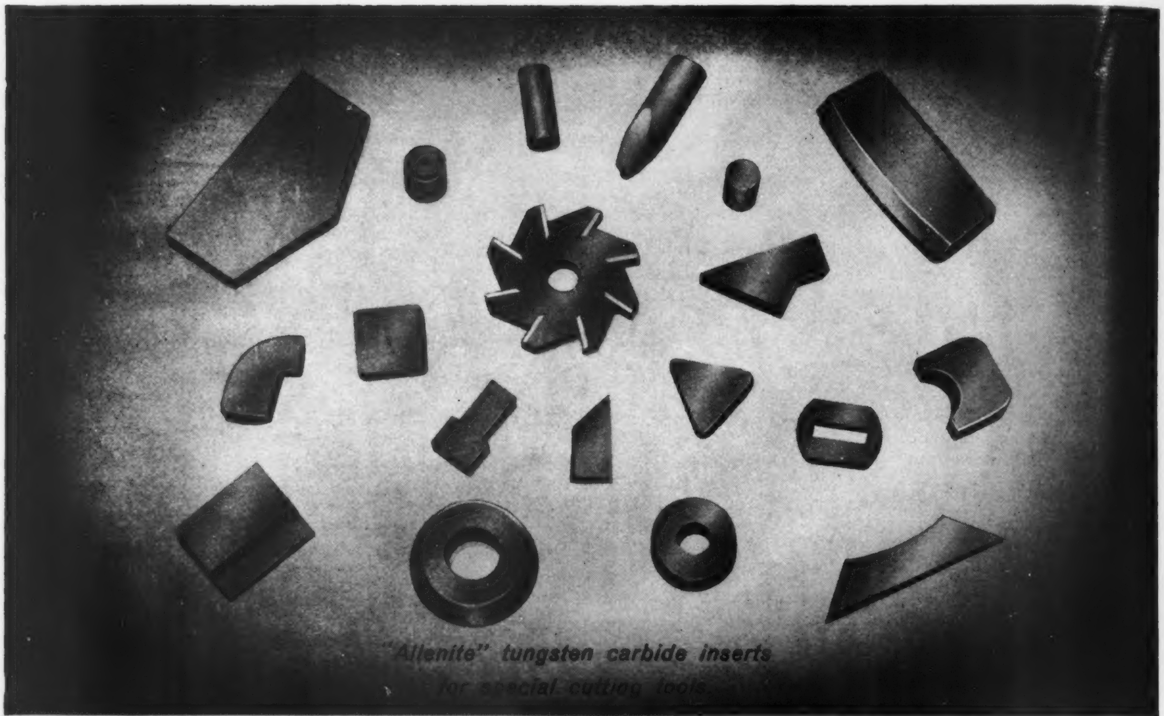

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The research which Edgar Allen have put into their manufacture of Stag 'Allenite' tungsten carbide cutting materials, including the addition of special elements to modify and improve their characteristics, has resulted in a range which gives outstanding performances in high-speed production with long tool life between grinds.

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10 different grades of Stag 'Allenite' are made to meet applications which include cutting, percussive drilling, wear and abrasion resistance, chemical inertness, etc. We are at all times willing to advise, as care in choosing the right grade ensures the best possible results in machining steels, cast iron, non-ferrous metals, plastics, glass, etc.

EDGAR ALLEN & CO. LIMITED
IMPERIAL STEEL WORKS · SHEFFIELD 9

"Allenite"
PLOWRAKE and PLOWCAST Tools

PLOWRAKE
for planing steel

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for planing cast iron.

The success of Plowrake tools in planing steel led to a demand for similar tools for planing cast iron. Plowcast tools will stand up better than any in planing cast iron, especially with interrupted cutting or on machines not in the best of condition.

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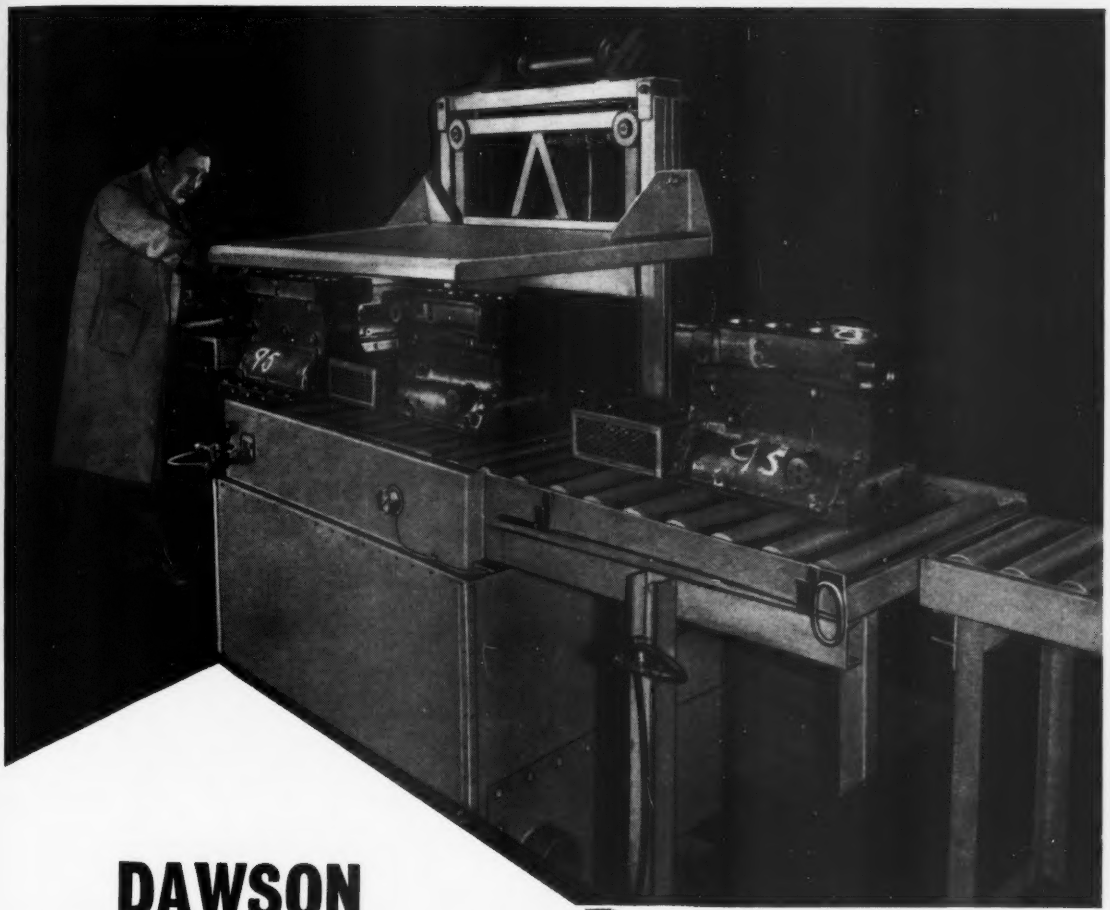

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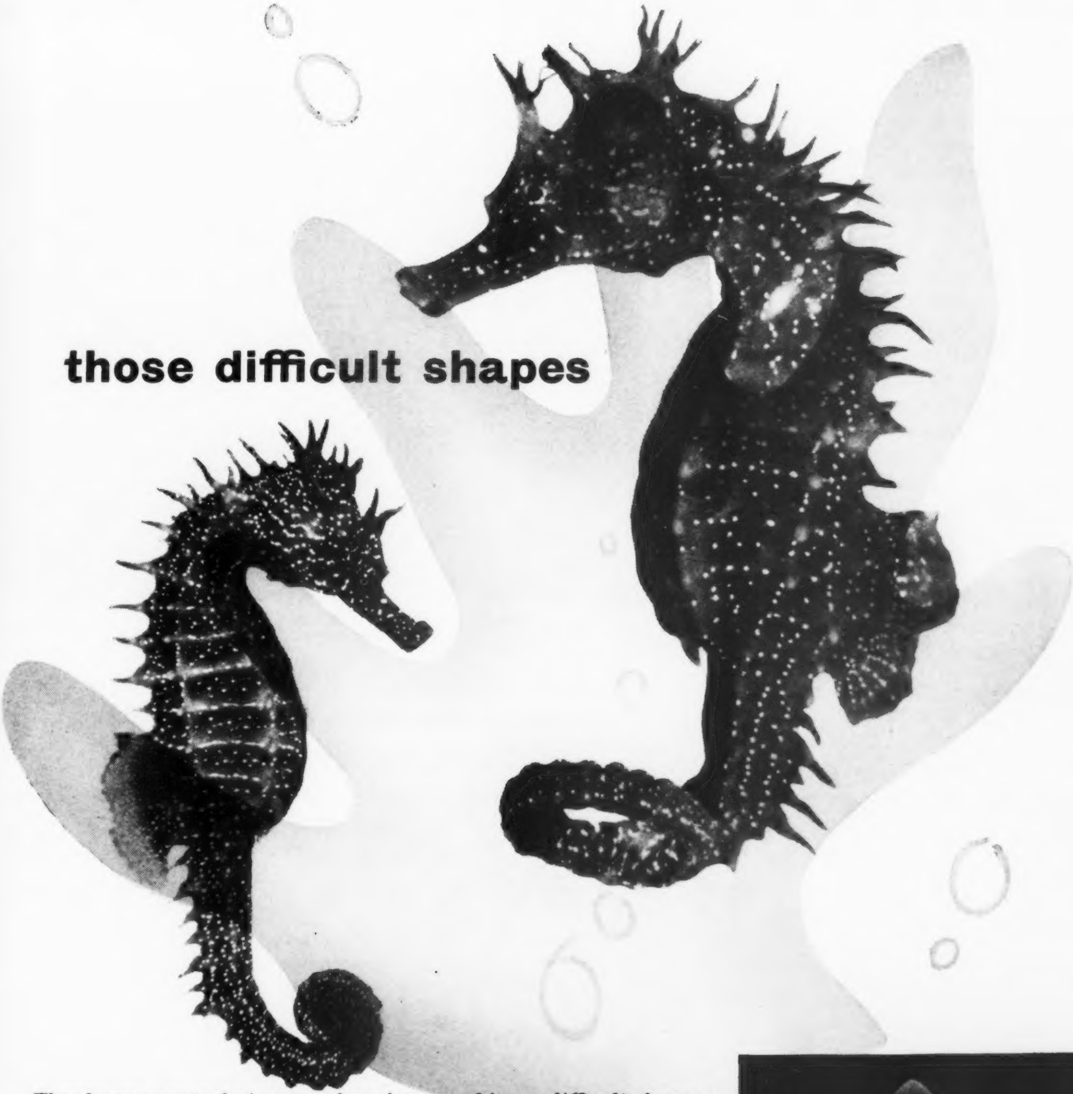
those difficult shapes



Thanks to new techniques and modern machinery difficult shapes present no problem when made by the Powder Metallurgy process. FERROCITE produces the answer to the production in quantity of machine parts with high wearing resistance and load carry capacity. FERROCITE parts are produced by compressing selected metal powders in accurately made dies. Complex contours can be produced. The oil-satin finish eliminates further machining and facilitates assembly. To gain the many advantages of the Powder Metallurgy process it is often possible to modify an existing design without loss of efficiency in operation.

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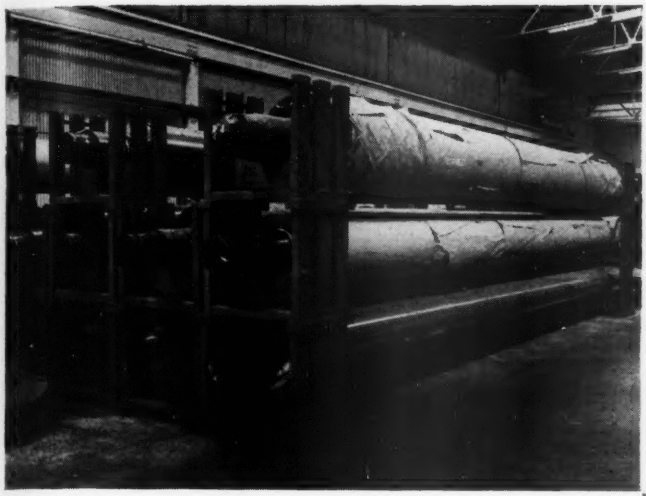
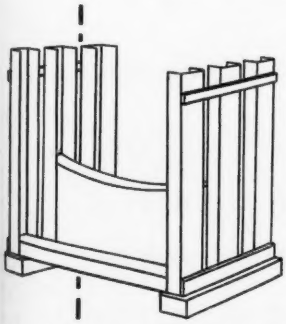


ROLL PALLETS for GIANT ROLLS

THE PROBLEM—to store 8 12-ton rolls at the Aylesford Paper Mills of Albert E. Reed & Co. Ltd.

THE SOLUTION—specially designed R. O. roll pallets, strong enough to support the great weight when stacked 3 high, adjustable for variation in length, designed to protect the rolls from the slightest damage.

THE PROOF—Reeds found these R.O. pallets both time-saving and money-saving.



SPECIFICATION: The pallets are of an all-steel welded construction 30 in. x 20½ in. x 27 in. They comprise 3 vertical "U" channels on either side of base. Vertical channels are braced for extra strength. Cradles are made from good quality hardwood and are arranged to fit inside or between any of the vertical channels of the pallet. Pallets are stackable and in normal practice 3 high is usual.

Rubery Owen solve all kinds of handling and storage problems for all kinds of people. They could solve yours, too.

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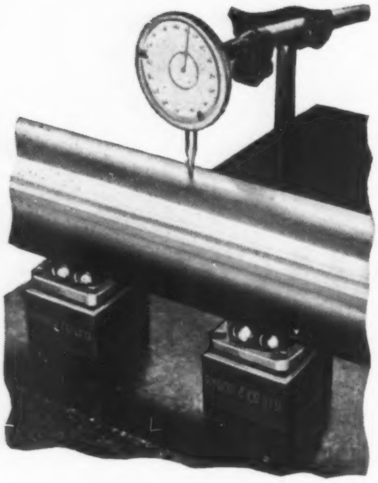

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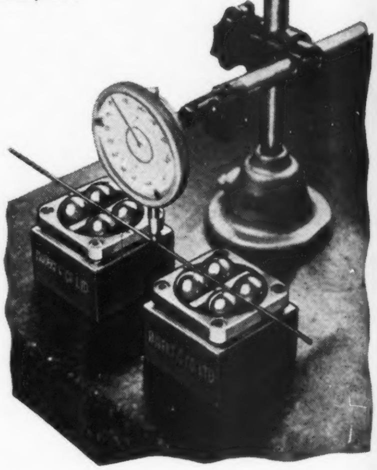

Model B without clamp
(for use in upright position)

Size	*Ball dia.*	*Order No.*	*Per Pair*
1	$\frac{1}{2}$ in.	93	**£5. 5.0**
2	$\frac{15}{16}$ in.	94	**£7.15.0**
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(can be used on any side)

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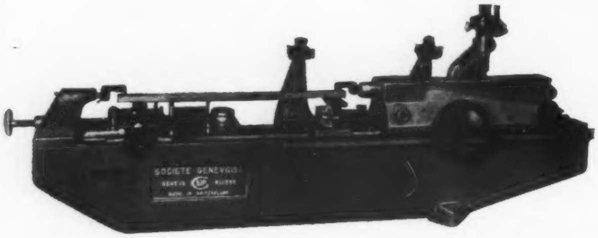

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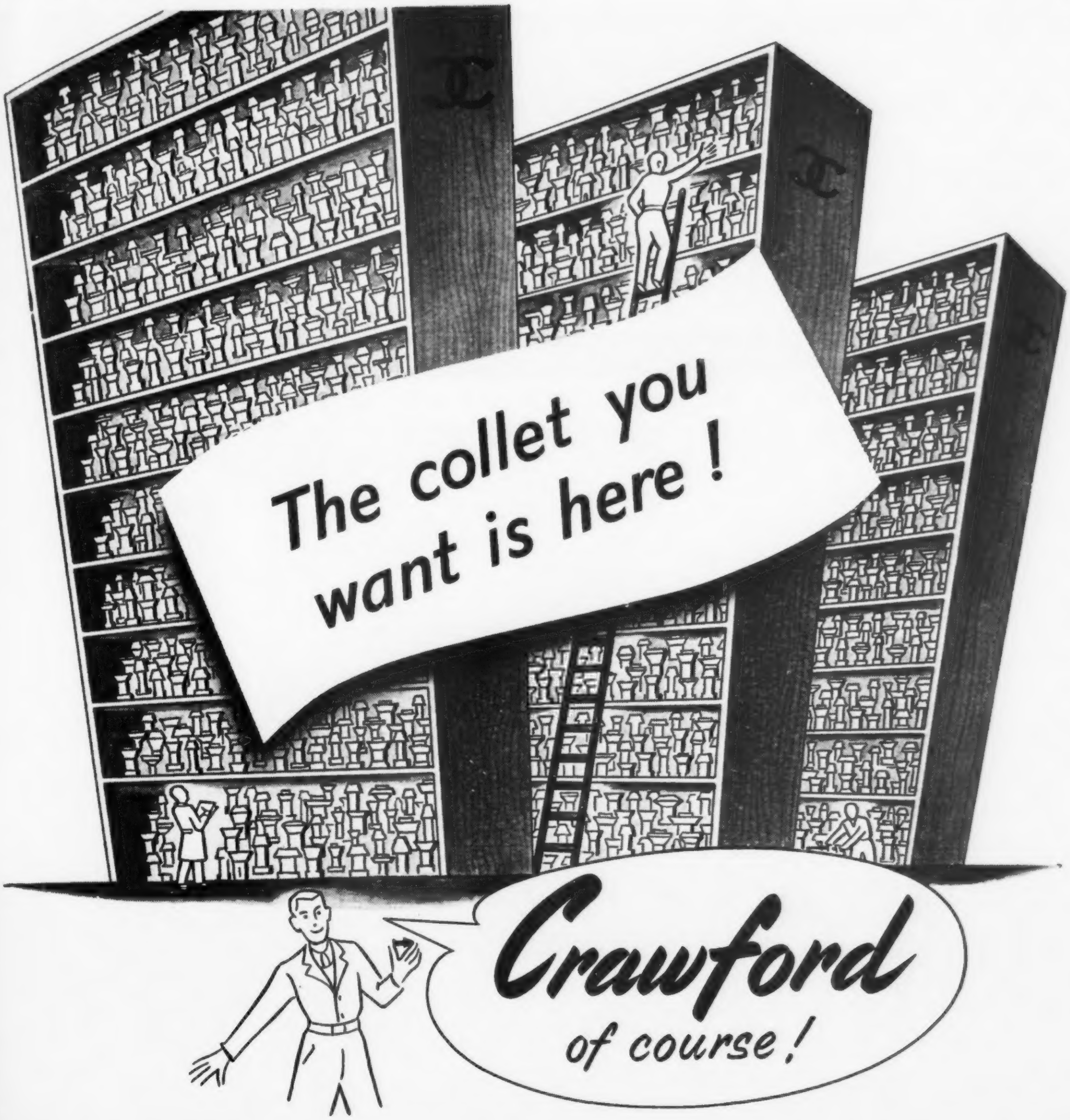
162 GRANGE ROAD COVENTRY TEL: 88584 **A·I·D APPROVED**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Write for illustrated leaflet A.207.

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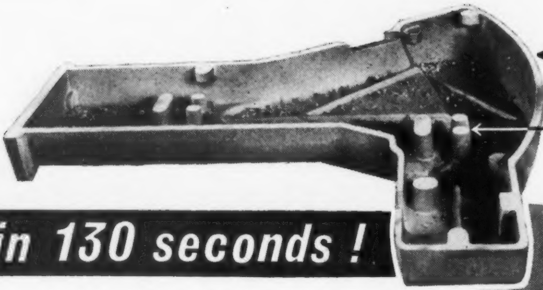
This aluminium component is

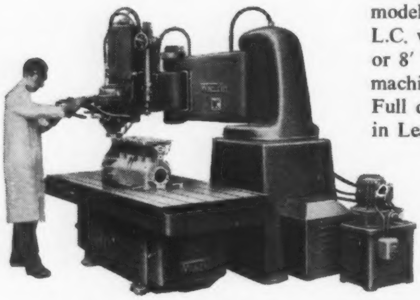


← JOINT FACE

← 13 BOSSES
(6 Different Depths)

face-milled in 130 seconds !

HERE is a typical example of the amazing time and cost cutting advantages of machining light alloys on a Wadkin Articulated Arm Router, L.C. This router face-mills the weighing machine component, shown above, in a fraction of the time taken by any other method and yet its initial cost is relatively low. Three models are available: heavy duty type L.C. with either 6′ 0″ reach (illustrated) or 8′ 0″ reach, and the medium capacity machine, type L.C.6 with canting table. Full details of these machines are given in Leaflet No. 945, available on request.



Wadkin Articulated Arm Router L.C. face-milling an engine crank-case.

Wadkin

HIGH SPEED MACHINE TOOLS

Wadkin Articulated Arm Router L.C. face-milling the weighing machine component shown above.

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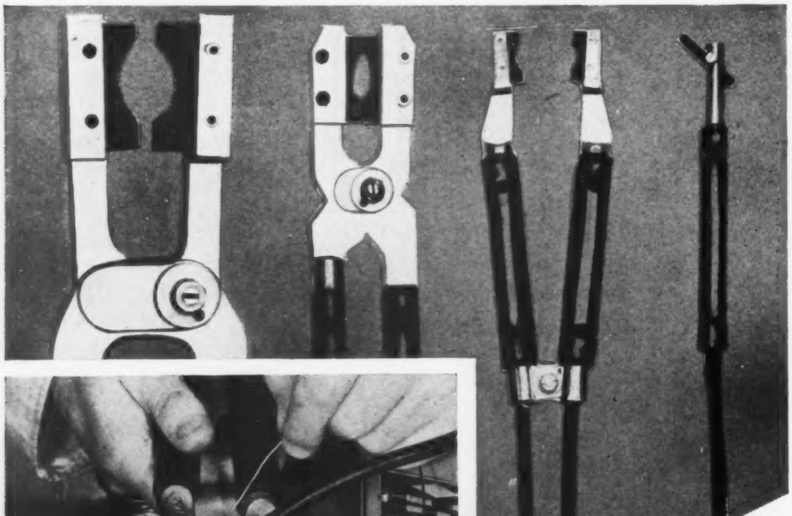

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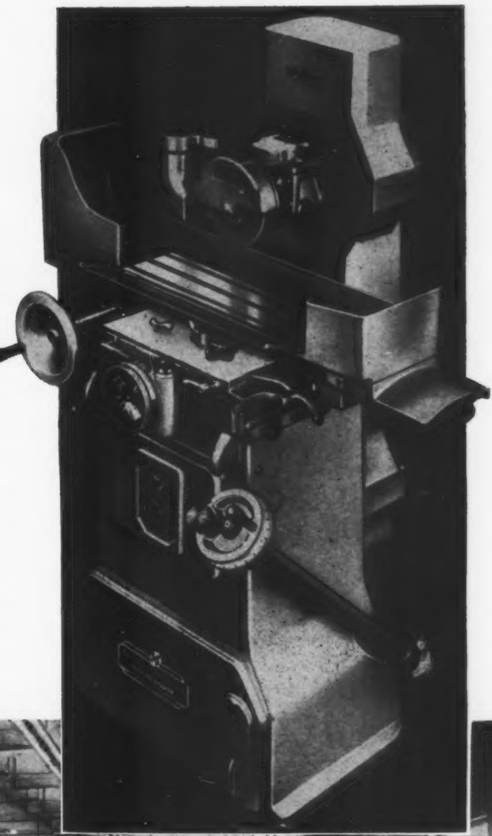
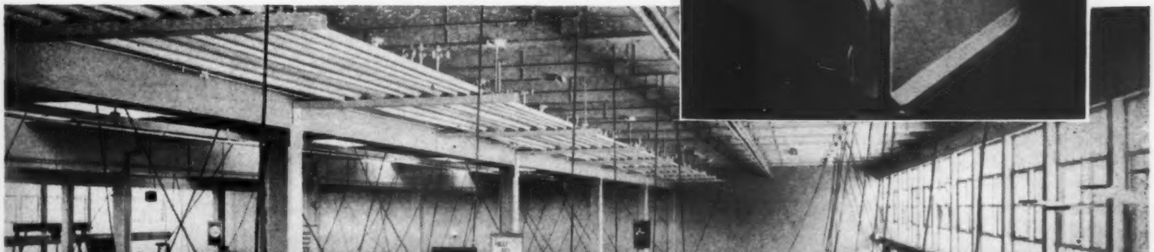


'540' SURFACE GRINDERS

Jones-Shipman '540' Surface Grinders are used extensively at the various factories in the Mullard group of companies. This world famous electronics organisation relies on these machines for manufacturing the tools and fixtures necessary for producing many of their wide range of products. The merits of the '540' are universally known. They are installed in all the best toolrooms giving first class service and performance. When you need a toolroom surface grinder specify Jones-Shipman model '540' 6″ × 18″ capacity.



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Electrical Aids in Industry *Data Sheet* **No. 16**

Speed control of Electric Motors

'Variable' speed may involve two or three (or more) speed steps or infinitely variable (stepless) speed control. It is this latter type which is considered below. Of the many advantages of electric drives, the opportunity offered for infinitely variable speed control is outstanding. Unfortunately this advantage is not used as much as it might be to increase the speed of working, and to improve productivity and quality.

Principal Factors Affecting Choice of Drive

(a) First cost, (b) Efficiency, (c) Speed range, (d) Regulation, (e) Power-to-weight ratio, (f) Availability of supply, (g) Maintenance and reliability, (h) Change in power and torque over the speed range, (i) Simplicity of control gear, (j) Effect of variation in supply, (k) Power factor, (l) Characteristics of the load, (m) Operational environment, (n) Braking requirements.

This list is not meant to be all-embracing, for there well may be factors not mentioned which could prove conclusive in the choice of a drive.

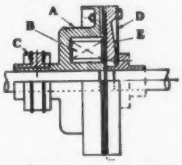
The following are some methods of obtaining infinitely variable speeds:

Alternating Current Motors

The vast majority of electric drives in use today employ A.C. motors. Although not quite so flexible as D.C. motors in the matter of speed control, there are available many types which give a large measure of speed variation.

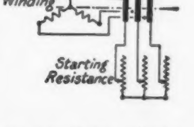
INDUCTION MOTORS. Although the squirrel-cage motor is essentially a constant-speed machine, it is much used for stepless variable speed drives with one of the following types:

(a) Eddy-current coupling,
(b) Ferro-magnetic particle coupling,
(c) Mechanical drives, e.g. belt drives and friction drives,
(d) Hydraulic variable speed drives.



A, Magnet body; B, Magnet coil; C, Collector gear; D, Spring plate; E, Armature.

SLIP-RING MOTOR. The slip-ring motor, which costs more than the squirrel-cage motor, can be varied in speed by means of the resistors in the rotor circuit used for starting. The amount of resistance in circuit can be varied in steps by means of different forms of control gear operated by hand, push-button or automatically controlled contactors.



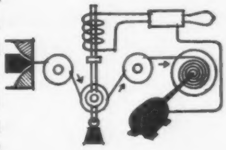
A.C. COMMUTATOR MOTORS. These are three-phase induction motors provided with additional windings which, through a commutator and brushes, permit speed adjustment in either direction below and above synchronous speed. The brush gear can be automatically controlled so as to vary the speed according to a known programme or cycle of operation such as in spinning frames. The Schrage and similar motors are refinements of this type.

Ward-Leonard System

In this system the armature of a D.C. motor is supplied at variable voltage from a separate generator. The generator may be driven by an A.C. or D.C. motor directly coupled to it and to an exciter which supplies the field windings of the generator and main motor. By means of a potentiometer resistance, with mid-point connected to one terminal of the generator field windings, the generator voltage may be varied from maximum to zero.

Electronic Motor Control

Motor speeds can be controlled accurately by electronic methods. Such drives can respond in any desired manner to variations in one or more variables and several drives can be interlocked so that their speeds are always in the same ratio. A typical application is on several separate conveyors. The system can be speeded up or slowed down from a 'master' controller, but for 'running in' purposes the speed of each drive can be individually regulated. Electronic speed control has been successfully applied where human control is not possible, e.g. in register control. In this example print must always be placed at exact positions on packaging material. The sketch shows electronic control of wire tension in drawing operations.



Direct Current Motors

While it is unlikely that a mains supply of D.C. will be available, the striking advantages of D.C. motors sometimes make it worth while installing a rectifier, e.g. a motor-generator set, a mercury-arc or a semi-conductor. The speed of D.C. motors is easily controlled by inserting a resistance in series with the motor. Although this can result in a certain amount of wasted electricity, the benefits derived will often heavily outweigh such losses.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available —' Electric Motors and Controls ' is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

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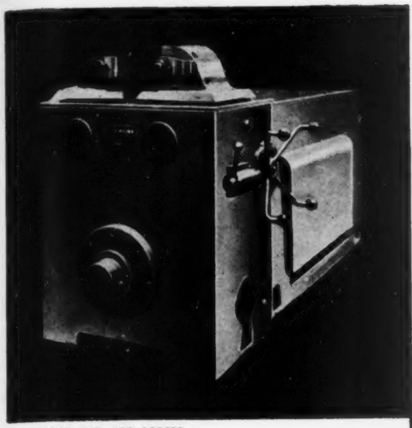

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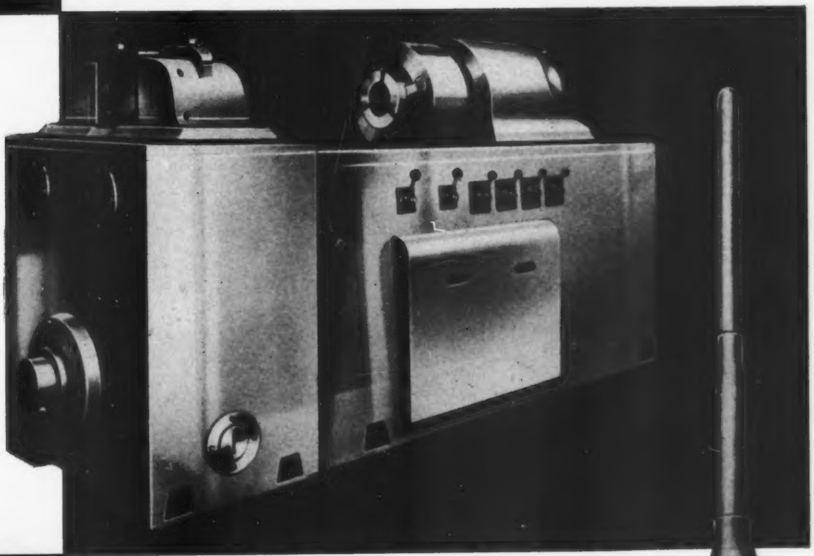

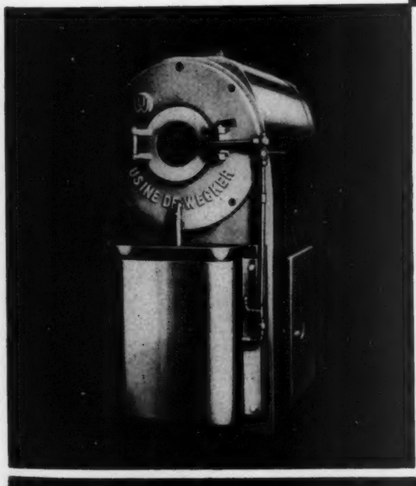

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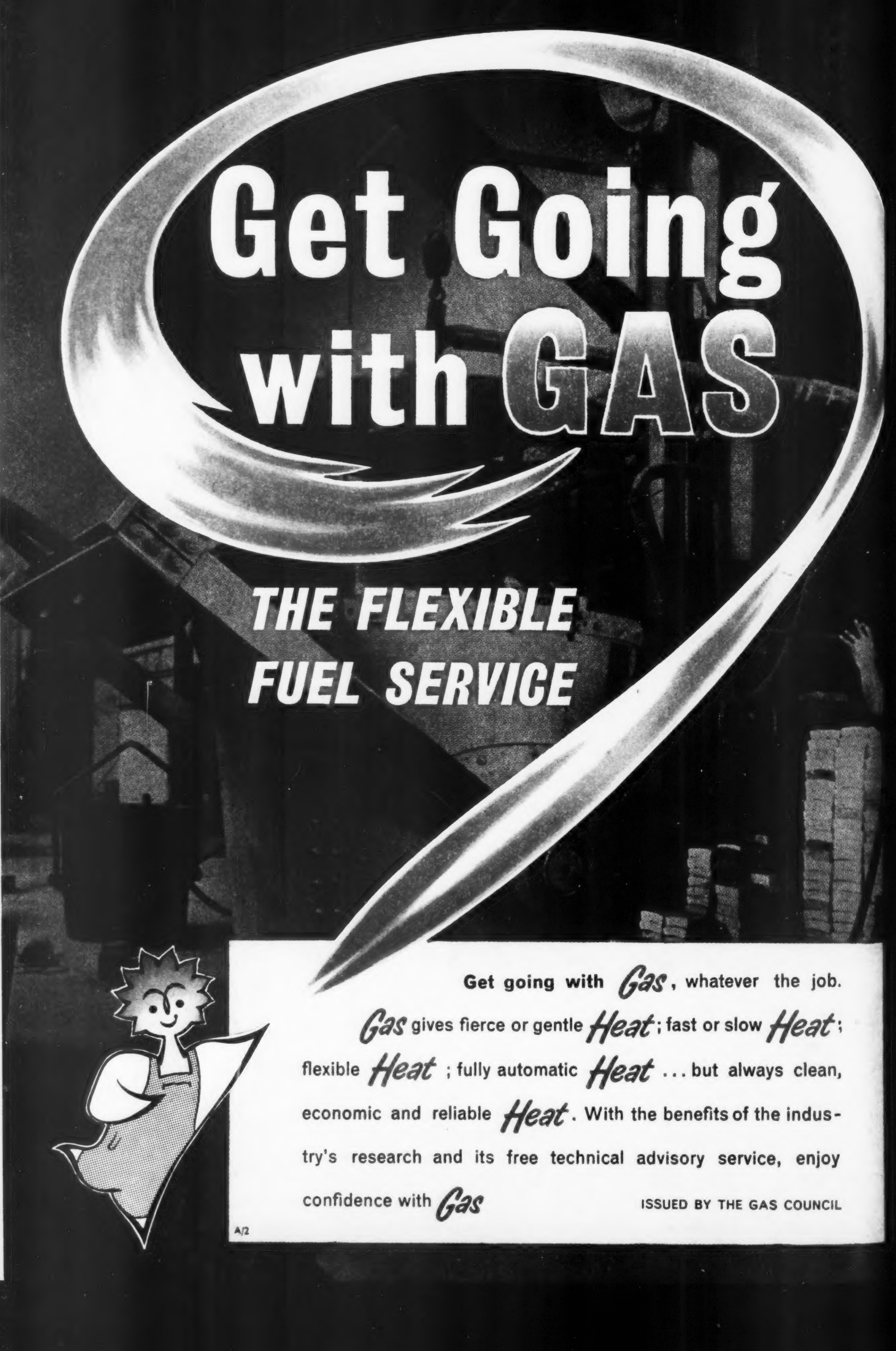
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